3 Building Envelope Requirements

The building envelope is responsible for the most significant loads that affect heating and cooling energy use. The principal components of heating loads are building envelope infiltration as well as conduction losses through building envelope components – including walls, roofs, floors, slabs, windows and doors. Solar gains through the windows dominate cooling loads in conditioned buildings, but loads through the ceiling/roof and walls are also significant.

3.1 Overview

3.1.1 Introduction

The Standards have both mandatory measures and prescriptive requirements that affect the design of the building envelope. The mandatory measures and prescriptive requirements establish a minimum performance level, which can be exceeded by other compliance options and construction practices resulting in greater energy savings.

Common strategies for exceeding the minimum energy performance level include the use of better components such as more insulation, higher efficiency windows, housewrap, radiant barriers, and higher efficiency heating, cooling and water heating equipment.

Design and construction practice options are discussed later in this chapter.

Those compliance options that are recognized for credit in the performance approach are called *compliance options*. Compliance options have eligibility criteria that must be satisfied before compliance credit is offered. Design options that save energy but for which there is no compliance credit are also discussed.

For the building envelope, field verification and diagnostic testing procedures exist for insulation quality and for reduced infiltration, and both are compliance options. Field verification and diagnostic testing is a way to ensure that the energy efficiency that shows up in the calculations and on the plans makes its way to the homeowner.

Following this overview, this chapter is organized by building system or building envelope component, as follows:

- Fenestration, including windows, doors, and skylights
- Insulation
- Thermal Mass
- Infiltration and Air Leakage
- Vapor Barriers and Moisture Protection
- Roofing Products (Cool Roof)

Within each of these sections, the material is generally organized as follows:

- Mandatory measures
- Prescriptive requirements
- Compliance options
- Compliance and enforcement

3.1.2 Building Orientation

The following definitions of east-, north-, west-, and south-facing apply only to the prescriptive packages and master plans analyzed according to the multiple orientation. In the computer methods the actual building orientation must be used, except in the case of master plans as stated above.

East-Facing

"East-facing is oriented to within 45 degrees of true east, including 45°0'0" south of east (SE), but excluding 45°0'0" north of east (NE)." [§101]

The designation “East-Facing” is also used in production buildings using orientation restrictions (e.g., Shaded Areas: East-Facing).

North-Facing

"North-facing is oriented to within 45 degrees of true north, including 45°0'0" east of north (NE), but excluding 45°0'0" west of north (NW)." [§101]

South-Facing

"South-facing is oriented to within 45 degrees of true south, including 45°0'0" west of south (SW), but excluding 45°0'0" east of south (SE)." [§101]

The designation “South-Facing” is also used in production buildings using orientation restrictions (e.g., Shaded Areas: East-Facing).

West-Facing

"West-facing is oriented to within 45 degrees of true west, including 45°0'0" due north of west (NW) but excluding 45°0'0" south of west (SW)." [§101]

The designation “West-Facing” is also used in production buildings using orientation restrictions (e.g., Shaded Areas: West-Facing).

3.1.3 What’s New for 2008

With the 2005 Standards, the maximum fenestration area was modified, credit is offered for insulation construction quality, and high performance replacement windows are required in existing homes. With the 2008 update to the Standards, the fenestration U-factor has been reduced for most climate zones in Package C and Package D. The SHGC has also been reduced in selected climate zones in these Packages. Package E is new for the 2008 and is for fenestration products with higher U-factors but with enhanced structural characteristics; the new package is shown to have the energy equivalency of Package D.

Fenestration

With the 2008 update to the Standards, the Package C U-factors are set at 0.38 for all climate zones. For Package D, the U-factors are set at 0.40 for all climate zones. In addition, in Package C there are new 0.40 SHGC requirements in climate zones 3, 5, and 6; in Package D, there are new 0.40 SHGC requirements in climate zones 5 and 6, and in climate zone 15 the SHGC has been reduced to 0.35.

One of the impacts of lower U-factors and SHGC is that the amount of credit available for installing high performance fenestration products has been significantly reduced. Prior to the 2008, high performance glazing option was used to avoid duct sealing and other prescriptive measures that required third party field verification; under the 2008 Standards, this option may not be as attractive as the amount of credit for installing high performance fenestration is reduced.

In Package E the U-factors are higher (less efficient); however, the SHGC are equal or lower than Package C and Package D. Therefore; Package E provides improvements to other energy features thus showing overall equivalency to Package D. The Package E allows more flexibility using window product in a home by providing offsetting improvements to other conservation measures. The new package is shown to have energy equivalency to Package D.

All manufactured fenestration must meet the minimum efficiency in the prescriptive/compliance packages. Manufactured fenestration not certified by NFRC must use the CEC Default values found in Table 116-A and Table-116-B in the Standards and documented according to §10-111 labeling requirements. See Sample Default Temporary Label below. Only Package E has fenestration U-factors high enough that some default table window U-factors are compliant. In climate zones where there is a SHGC requirement, no fenestration that is not NFRC certified can meet the SHGC requirement. The prescriptive packages do allow a very small area of non-compliant fenestration to be installed; see Section 3.2.3 for more information.

Default Temporary Label

Although there is no exact format for the CEC default temporary label, it must be clearly visible and large enough for the enforcement agency field inspectors to read easily and it must include all information required by the regulations. The suggested label size is 4 in. x 4 in. The label must have the words “California Energy Commission Default U-factor” followed by the correct value for that fenestration product from Table 116-A in the Standards and the words “California Energy Commission Default SHGC” followed by the correct value from Standards Table 116-B. The U-factor and SHGC default values should be large enough to be visible from 4 ft. For skylights, the label must indicate when the product was rated with a built-in curb.

If the product claims the CEC default U-factor for a thermal-break product, the manufacturer must certify that the thermal-break criteria, upon which the default value is based are met. Placing the term "Meets Thermal-Break Default Criteria" on the temporary label meets the requirement.

California Energy Commission Default Label	**XYZ Manufacturing Co.**
Key Features:	Double-pane Operable Metal, Thermal Break Air space 7/16 in. or greater Tinted
California Energy Commission Default U-factor 0.61	**California Energy Commission** Default SHGC 0.53

Product meets the air infiltration requirements of §116(a)1, U-factor criteria of §116(a)2, and SHGC criteria of §116(a)3, 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.

Sample Default Temporary Label

Roofing Products (Cool Roof)

Roofing products with high solar reflectance and thermal emittance are referred to as "cool roof" which is the outer layer of a roof. Cool roofs are now a prescriptive requirement for both low-slope and steep-slope roof application on a residential buildings. To be considered a cool roof the roofing products must be tested and labeled by the Cool Roof Rating Council (CRRC).

Also, Solar Reflectance Index (SRI) is a new concept in the 2008 Standards; in lieu of meeting a thermal resistance and an aged solar reflectance requirement, compliance can be shown by meeting a minimum SRI. To calculate the SRI the 3-year aged value of the roofing product must be used in conjunction with the thermal emittance. By using the SRI calculator, a cool roof may comply with an emittance lower than 0.85 as long as the aged reflectance is higher; alternately, SRI can be used to demonstrate compliance by trading off a lower aged solar reflectance with a higher thermal emittance.

3.2 Fenestration

Windows, glazed doors, and skylights have a significant impact on energy use in a home. They may account for up to 50 percent of residential space heating loads, and for homes that are air-conditioned, up to 50 percent of the cooling load. The size, orientation, and types of fenestration products can dramatically affect the overall energy performance of a house. Glazing type, orientation, shading and shading devices not only play a major role in the building's energy use but can affect the operation of the HVAC system and the comfort of the occupants.

3.2.1 Relevant Sections in the Standards

The Standards deal with fenestration in several ways and places:

1. §10-111 (Administrative Standards) establishes the rules for rating and labeling fenestration products and establishes the NFRC as the supervising authority.
2. §116(a)1 sets air leakage requirements for all manufactured windows whether they are used in residential or nonresidential buildings.
3. §116(a)2 and 3 require that the U-factor and the solar heat gain coefficient (SHGC) for manufactured fenestration products be determined using NFRC procedures or use default fenestration values in Standards Table 116-A and Table 116-B.
4. §116(a)4 requires that manufactured fenestration products have both a temporary and permanent label. The temporary label shall show both the U-factor and the SHGC and verify that the window complies with the air leakage requirements.
5. §116(b) has default U-factors and SHGC values that are to be used for field-fabricated fenestration and exterior doors that do not have an NFRC rating.
6. §117 requires that openings around windows and doors be caulked, gasketed, weatherstripped or otherwise sealed to limit air leakage.
7. §151(f)3 Exception allows up to 3 ft^2 of the glazing installed in doors and up to 2 ft^2 of tubular skylight with dual-pane diffusers to have an assumed U-factor equivalent to the Package requirements.
8. §151(f)3 and 4 have the prescriptive requirements for fenestration in low-rise residential buildings. These include requirements for maximum glazing area, maximum U-factor, and for some climate zones, a maximum SHGC requirement.

9. §152(a) sets the fenestration area requirements for residential additions and requires that new windows meet the prescriptive requirements.
10. §152(b) establishes that replacement windows in existing residences meet the prescriptive requirements. Performance compliance options (existing plus alteration) are also available.

3.2.2 Mandatory Measures

The Standards define three types of fenestration products that face different mandatory measures:

- **Manufactured products** are delivered pre-assembled from the factory. This is the most common type of fenestration in residential construction.
- **Site-built products** are glazed or assembled on site using factory prepared systems. These are more common in nonresidential construction and include storefront and curtainwall systems. The glazing contractor may also pre-assemble site-built fenestration at his or her shop before final installation. For unlabeled site-built fenestration use default values from Standards Table 116-A for U-factor and Table 116-B for SHGC, otherwise, select site-build fenestration from NFRC's Certified Products Directory. See http://www.NFRC.org.
- **Field-fabricated products** are built on site using standard dimensional lumber or other materials not intentionally prepared for use as a fenestration product. For field-fabricated fenestration use default values from Standards Table 116-A for U-factor and Table 116-B for SHGC.

Complete definitions can be found in the Reference Joint Appendices JA1.

Air Leakage

§116(a)1

Manufactured Fenestration Products. Manufactured fenestration products, including exterior doors, must be tested and certified to leak no more than 0.3 cubic feet per minute (cfm) per ft² of window area. For a window that has an area of 10 ft², the maximum leakage would be 10 ft² times 0.3 cfm/ft² or a total leakage of 3 cfm. This is equal to about 86 in³ per second or about a quart and a half of air each second. This mandatory measure applies to all manufactured windows whether they are used in new residential or nonresidential buildings.

To determine leakage, the test procedure that manufacturers use is either NFRC 400 or ASTM E283, which are essentially the same.

Site-built Products. There are no specific air leakage requirements for site-built fenestration products but the Standards require limiting air leakage through weatherstripping and caulking.

Field-fabricated Products. No testing is required for field-fabricated fenestration products; however, the Standards require limiting air leakage through weatherstripping and caulking.

Exterior Doors. Exterior doors must meet the following requirements:

- Manufactured exterior doors must be certified as meeting an air leakage rate of 0.3 cfm/ft² of door area of §116(a)1, which is the same as windows.
- They must comply with the requirements of §117, as described below in “Joints and Other Openings,” e.g., they must be caulked and weatherstripped if field-fabricated.
- Any door whose surface area is more than one-half glass is a fenestration product and must comply with the mandatory and prescriptive measures and other Standards requirements for fenestration products.

U-factor and SHGC Ratings

§116(a)2 and §116(a)3

Table 116-A

Table 116-B

Manufactured Fenestration Products. The mandatory measures require that both the U-factor and the SHGC of manufactured fenestration products be determined from NFRC’s Certified Product Directory or from Energy Commission-approved default tables. At the time of inspection, the actual fenestration U-factor and SHGC values as shown on NFRC labels or in the default tables must result in equal or lower overall energy consumption than the values indicated on the compliance documents. The default U-factors are contained in Standards Table 116-A, and the default SHGC values are contained in Standards Table 116-B (also in Appendix B of this compliance manual). A directory of NFRC certified ratings is available at http://www.NFRC.org.

Commission default values in both Standards Tables 116-A and 116-B are on the poor side of the performance range for windows. To get credit for advanced window features such as low-e (low-emissivity) coatings and thermal break frames, the window manufacturer must have the window tested, labeled, and certified according to NFRC procedures. Figure 3-1 shows an example of an NFRC-approved temporary fenestration label.

Figure 3-1 – NFRC Temporary Label

Requiring that SHGC and U-factor be calculated using a common procedure ensures that the performance data for fenestration products are more accurate and that data provided by different manufacturers can be more easily compared. The test procedure for U-factor is NFRC 100, and the test procedure for SHGC is NFRC 200.

Site-built Fenestration Products. For low-rise residential construction, site-built products are treated the same as manufactured products: U-factor and SHGC values must come from NFRC ratings or from Standards Tables 116-A and 116-B. Note that different alternative default values apply to nonresidential projects; default values may be found in the Reference Nonresidential Appendices NA6.

Field-fabricated Products §116(b). Field-fabricated fenestration must always use the Energy Commission default U-factors from Standards Table 116-A and SHGC values from Table 116-B.

For non-field-fabricated products, acceptable methods of determining U-factor are shown in Table 3-1. Acceptable methods of determining SHGC are shown in Table 3-2.

Table 3-1 – Allowable Methods for Determining U-factors

Fenestration Category			
U-factor Determination Method	Manufactured Windows	Site-Built Fenestration	Field-Fabricated Fenestration
NFRC-100	✓	✓	N/A
Standards Table 116-A	✓	✓	✓

Table 3-2 – Methods for Determining Solar Heat Gain Coefficients

	Fenestration Category		
SHGC Determination Method	Manufactured Windows	Site-Built Fenestration	Field-Fabricated Fenestration
NFRC-200	✓	✓	N/A
Standards Table 116-B	✓	✓	✓

Temporary and Permanent Labels

See §10-111(a) and §116(a)4

Manufactured Fenestration Products. The Standards require that manufactured windows have both temporary and permanent labels that show the NFRC performance characteristics. The temporary label shows the U-factor and SHGC, for each rated window. The label must also show that the window meets the air infiltration criteria. The temporary label must not be removed before inspection by the enforcement agency.

The permanent label must, at a minimum, identify the certifying organization and have a number or code to allow tracking back to the original information on file with the certifying organization. The permanent label also can be inscribed on the spacer, etched on the glass, engraved on the frame, or otherwise located so as not to affect aesthetics.

Site-Built Fenestration Products. Labeling requirements apply to site-built fenestration products as well, except that a label certificate may be provided in accordance with NFRC 100 in place of an attached temporary label. The label certificate is a document that verifies the performance of the site-built fenestration product but that is not physically attached to the product. The label certificate is kept at the job site by the contractor for field inspector verification.

Field-Fabricated Fenestration Products. A label is not required for field-fabricated fenestration products, but must use the default values in Table 116-A and Table 116-B from the Standards.

Example 3-1

Question

My home will have a combination of window types, including fixed, operable, wood, metal, etc., some of which are field-fabricated. What are the options for showing compliance with the Standards?

Answer

For field-fabricated windows, you must select U-factors and SHGC values from the default tables (Tables 116-A and 116-B from the Standards). Windows that are not field-fabricated must be labeled, either with an NFRC label or with a manufacturer's label that certifies the window to have a U-factor and SHGC from the default tables (again, Tables 116-A and 116-B). The manufacturer must label the window in accordance with §116(a)4. If the U-factors or SHGC values do not comply with the prescriptive requirements, the performance method must be used (see Chapter 7). To simplify data entry into the compliance software, you may choose the U-factor from Table 116-A that is the highest of any of the windows and use this for all windows. However, you must use the appropriate SHGC from Table 116-B for each window type individually.

Example 3-2

Question

When windows are labeled with a default value, are there any special requirements that apply to the label?

Answer

There are two criteria that apply to fenestration products labeled with default values. First, the Administrative Regulations (§10-111) require that the words "CEC Default U-factor" and "CEC Default SHGC" appear on the temporary label in front of or before the U-factor or SHGC (i.e., not in a footnote). Second, the U-factor and SHGC for the specific product must be listed. If multiple values are listed on the label, the manufacturer must identify, in a permanent manner, the appropriate value for the labeled product. Marking the correct value may be done in the following ways only:

1. Circle the correct U-factor and SHGC (permanent ink);
2. Black out all values except the correct U-factor and SHGC (permanent ink); or
3. Make a hole punch next to the appropriate values.

Example 3-3

Question

What U-factor do I use for an operable metal framed, glass block? What solar heat gain coefficient do I use for clear glass block? Does it need a label?

Can I use the default clear glass SHGC values for tinted windows?

Answer

For glass block, use the U-factor and SHGC values from Standards Tables 116-A and 116-B for the frame type in which the glass blocks are installed. The worst-case scenario would be metal-framed glass. The U-factor for metal framed glass block is from Table 116-A is therefore 0.87. The SHGC depends on whether the glass block has a metal or non-metal frame, and is operable or fixed or clear or tinted. For this example, the glass block is operable and clear, therefore the SHGC is 0.70. Glass block is considered a field-fabricated product and therefore does not need a label.

Yes, since using the default clear glass SHGC for tinted windows results in a net energy savings, these default values may be used for tinted windows.

Example 3-4

Question

Is there a default U-factor for the glass in sunrooms?

Answer

Yes. For the horizontal or sloped portions of the sunroom glazing, use the U-factor for skylights. For the vertical portions, use the U-factors for fixed windows, operable windows, or doors, as appropriate. As a simplifying alternative, the manufacturer may label the entire sunroom with the highest U-factor of any of the individual fenestration types within the assembly.

Example 3-5

Question

How are various door types treated in compliance documentation for U-factor and SHGC? How can I determine a U-factor and SHGC for doors when less the 50% of the door area is glass?

Answer

All doors with glass area greater than 50% of the door area, which includes French doors, are defined as fenestration products and are covered by the NFRC Rating and Certification Program. You may use either an NFRC-rated U-factor or a default glazed door U-factor from Table 116-A. The fenestration area for compliance documentation is the entire rough opening of the door (not just the glass area).

The SHGC for doors with glass area more than 50% may be determined in one of two ways:

1. Use the NFRC rated and labeled SHGC.

2. Refer to Standards Table 116-B. The SHGCs in this table have been pre-calculated based upon glazing type and framing type.

Doors with less than 50% glass areas are treated as a door with fenestration installed within the door. The glass area is calculated as the sum of the glass areas plus two inches on all sides (to account for framing). For prescriptive or performance approaches, use one of the following options for U-factor and SHGC:

• The NFRC label if one is available, or

• The default values from Standards Table 116-A and 116-B

The opaque part of the door is ignored in the prescriptive approach. If the performance approach is used for the glazing part of the door, an NFRC label or default values for U-factors and SHGC must be used, for the opaque portion of the door, a default value of 0.50 must be assumed. Alternatively, if available, NFRC values for U-factor and SHGC may be used for the entire door, including the opaque areas.

Example 3-6

Question

As a manufacturer of fenestration products, I place a temporary label with the air infiltration rates on my products. Can you clarify which products must be tested and certified?

Answer

Each product line must be tested and certified for air infiltration rates. Features such as weather seal, frame design, operator type, and direction of operation all affect air leakage. Every product must have a temporary label certifying that the air infiltration requirements are met. This temporary label may be combined with the temporary U- factor label.

Example 3-7

Question

Is a custom window “field-fabricated” for purposes of meeting air infiltration requirements?

Answer

No. Most custom windows are manufactured and delivered to the site either completely assembled or “knocked down,” which means they are a manufactured product. A window is considered field-fabricated when the windows are assembled at the building site from the various elements that are not sold together as a fenestration product (i.e., glazing, framing and weatherstripping). Field-fabricated does not include site-assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked down products, sunspace kits, and curtain walls).

Example 3-8

Question

What constitutes a “double-pane” window?

Answer

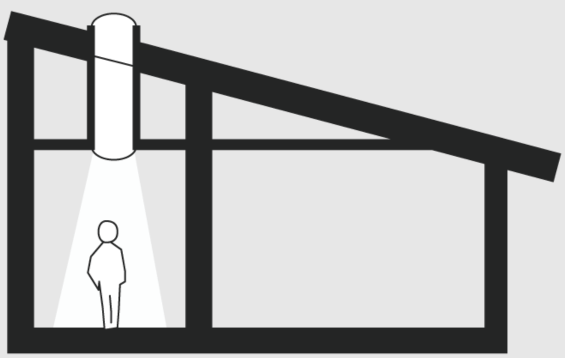
Double-pane (or dual-pane) glazing is made of two panes of glass (or other glazing material) separated by space (generally 1/4" [6 mm] to 3/4" [18 mm]) filled with air or other gas. Two panes of glazing laminated together do not constitute double-pane glazing.

Example 3-9

Question

To get daylight into a room in my new house, I plan on installing a tubular skylight using the performance approach. The skylight has a clear plastic dome exterior to the roof, a single pane ¼-inch (6 mm)-thick acrylic diffuser mounted at the ceiling, and a metal tube connecting the two. How do I determine the U-factor and SHGC that I will need to determine if I can comply with the Standards, if U_c is 1.20 and $SHGC_c$ is 0.85?

Answer



Tubular skylights are an effective means for bringing natural light into interior spaces. As a manufactured product, tubular skylights must have a temporary label.

There are three methods available for determining the U-factor for tubular skylights. The first is to use the default U-factor from Standards Table 116-A. This tubular skylight would be considered a metal frame, fixed, single-pane resulting in a U-factor of 1.19, which must appear on a label preceded by the words “CEC Default U-factor.” (A tubular skylight would have to have two panes of glazing with an air space of less than 2 inches (50 mm) between them at the plane of the ceiling insulation for it to be considered double-pane.)

The second method is to determine the U-factor from the Reference Nonresidential Appendix NA6, Equation NA6-1. The U-factor for this tubular skylight is based on the metal with no curb (Table NA-1). The U-factor for this skylight using Equation NA6-1 is 1.25, where U_t = (0.195 + (0.882 x 1.20)). This must appear on a label stated as “CEC Default U-factor 1.25.”

The third and best method, applicable if the skylight has been tested and certified pursuant to NFRC procedures, requires a label that states, “Manufacturer stipulates that this rating was determined in accordance with applicable NFRC procedures NFRC 100” followed by the U-factor.

There also are three methods available for determining SHGC. The first is to use the default table SHGC in Standards Table 116-B. This tubular skylight would be considered a metal frame, fixed, clear, single-pane product resulting in an SHGC of 0.83, which must appear on a label stated as “CEC Default SHGC 0.83.”

The second method also determines the SHGC from the Reference Nonresidential Appendix NA6, Equation NA6-2. The SHGC for this skylight using Equation NA6-2 is 0.81, where

$SHGC_t$ =(0.08 + (0.86 x 0.85)). This must appear on a label stated as "CEC Default SHGC 0.81."

The third method, applicable if the skylight has been tested and certified pursuant to NFRC procedures, requires a label that states, "Manufacturer stipulates that this rating was determined in accordance with applicable NFRC procedures NFRC 200 followed by the skylight's SHGC.

Example 3-10

Question

How would the U-factor and the SHGC be determined if the skylight in the example above has a dual pane diffuser (instead of single pane) mounted at the ceiling?

Answer

The procedure would be exactly the same as the example above, except that double pane U-factor and SHGC values from Standards Tables 116-A and 116-B would be used instead of single pane values. Note that up to 2 ft^2 of tubular skylight is assumed to have the U-factor required to meet prescriptive compliance or the Package D value for performance compliance (Exception to §151(f)3A).

3.2.3 Prescriptive Requirements

Prescriptive requirements described in this chapter typically refer to Package D. For a list of Package C and Package E features, refer to Tables 151-B and 151-D of the Standards (also in Appendix B of this document).

The prescriptive requirements specify a maximum U-factor, and, in climate zones where air conditioning is common, a maximum SHGC. In addition, the prescriptive requirements limit total glass area to a maximum of 20 percent of the conditioned floor area and west-facing glass to a maximum of 5 percent of the conditioned floor area in climate zones 2, 4, and 7-15. West-facing fenestration area includes skylights tilted to the west or tilted in any direction when the pitch is less than 1:12 (§151(f)3C).

Fenestration U-factor

With the 2008 update, the U-factor prescriptive Package D requirements for all climate zones is 0.40 or lower (see Table 3-3 for all packages U-factor requirements). However, for each building, up to 3 ft^2 of the glazing installed in doors and up to 2 ft^2 of tubular skylights with dual-pane diffusers at the ceiling are exempt from the prescriptive U-factor requirements. See Exception §151(f)3A. When using the prescriptive criteria, some windows may exceed the prescriptive requirement as long as the area-weighted average U-factor meets the requirement. Decorative or stained glass is an example that might not meet the prescriptive requirements unless weight-averaged with other fenestration. To calculate weight-averaged U-factors for prescriptive envelope compliance, see Form WS-2R in Appendix A of this manual.

The U-factor criterion applies to both windows and skylights. Most skylights are mounted on a curb, and the U-factor of such skylights according to NFRC procedures includes heat loss through a standardized portion of curb included in the tests. NFRC 100 includes the following:

If a skylight can be installed using more than one of the installation methods listed below, the skylight product line shall include all the pertinent options as individual products. The method in which a skylight is mounted will affect its U-factor. Mounting variations include these:

1. Inset mount, where the curb of the skylight extends into the rough opening on the roof;
2. Curb mount, where the outside of the curb is equal to the rough opening in the roof; and
3. Curb mount, where the inside of the curb is equal to the rough opening in the roof.

NRFC 100 also states the following:

1. Curb mounted skylights that do not have an attached integral curb when manufactured shall be simulated and tested installed on a nominal 2 x 4 (actual size 40.0 mm x 90.0 mm or 1.5 in. x 3.5 in.) wood curb made from Douglas Fir, with no knots.
2. The heat transfer characteristics of site-built curbs are not included in the NFRC rating and must be modeled as a part of the opaque building envelope. For compliance purposes with the low-rise residential standards, the U-factor for a skylight rated with any of the three mounting variations described above is applied to the area of the rough opening.

U-factors for skylights are therefore significantly higher than they are for windows, even when the construction of the skylight and the window are similar. This means that skylights will not generally comply with the prescriptive requirements, and any building that uses skylights will be forced to use the performance approach unless weight-averaging with other fenestration is used.

Table 3-3 – Maximum U-factors by Climate Zone in Packages C, D and E

Climate Zone	1	2-15	16
Package C - Maximum U-factor	0.38	0.38	0.38
Package D - Maximum U-factor	0.40	0.40	0.40
Package E - Maximum U-factor	0.50	0.57	0.45

SHGC

The standards set a maximum SHGC of 0.40 for homes constructed in all climate zones except 1, 3, and 16 where there are no SHGC requirements. The maximum SHGC requirements are in the climate zones where homes are more likely to be air conditioned. This requirement applies to the fenestration product without consideration of insect screens or interior shading devices. Other than skylights, the SHGC of windows and doors can be weight-averaged to meet the prescriptive requirement. West-facing glazing may not be averaged with non-west facing glazing. Weight-averaging must be done within the limitations on west-facing area allowance in §151(f)3C. The SHGC of all west-facing glazing may be averaged. The SHGC of all non-west-facing glazing may be averaged. Skylights must meet the SHGC requirement without weight-averaging. However, the skylight area and required SHGC must be included with calculations of the west-facing area.

A window or fenestration product that meets the SHGC criterion will typically have a special low-e coating that reduces solar gains. The coating also has other benefits, such as reducing the admittance of UV energy, which is the principal cause of fabric fading.

While a low-e coating is the most common way to comply with the SHGC requirements, the Standards offer other options: use an exterior shade screen or louver on the outside of the window or, for south facing windows, use a properly sized overhang. Both sunscreens and overhangs are discussed in the Compliance Options section.

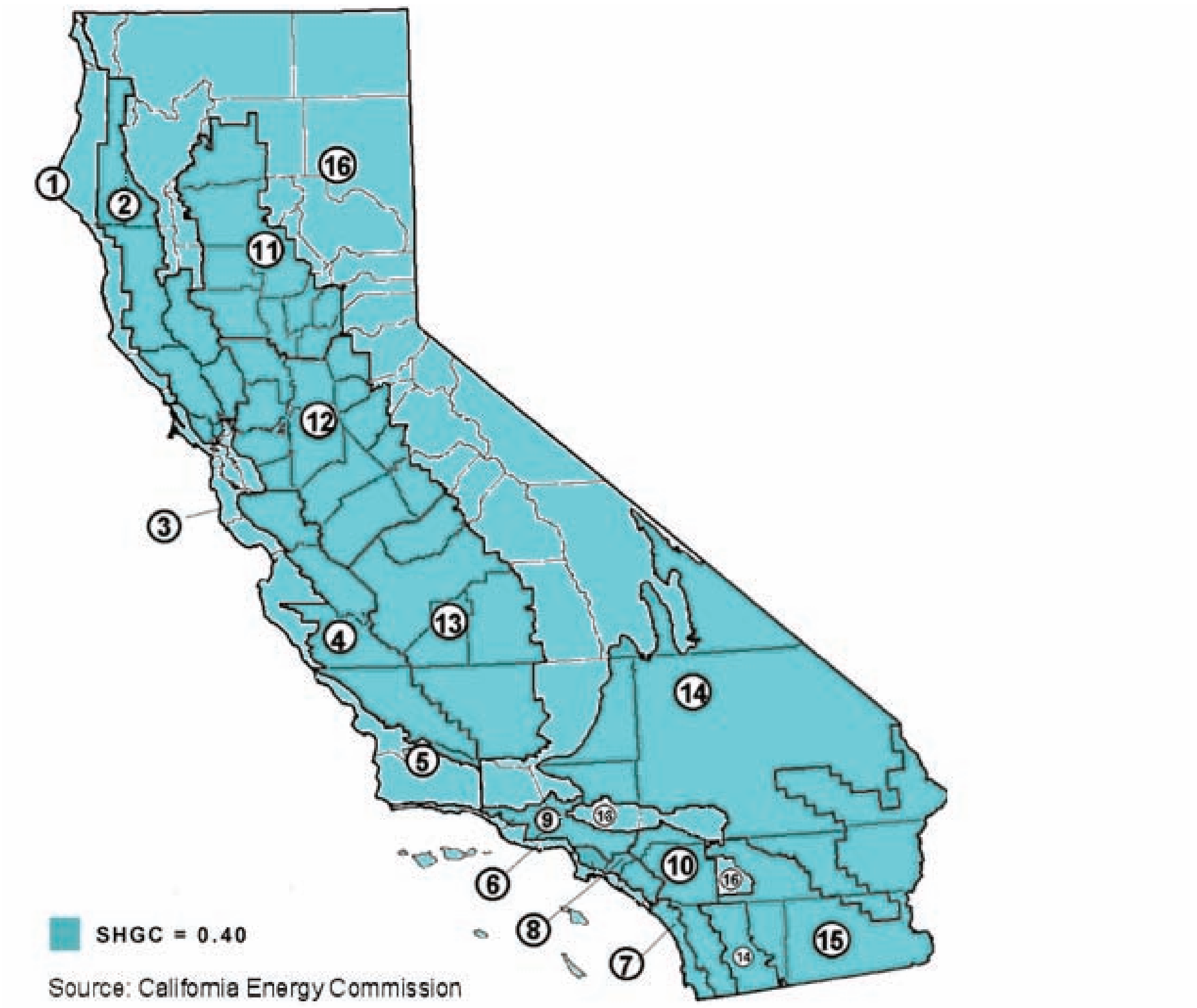


Figure 3-2 – Package D SHGC Criteria by Climate Zone

Table 3-4 – Package C, D and E SHGC Criteria by Climate Zone

Package C											
Climate Zone	1, 16	3	4	5	6	7	8, 9	10	2, 11-13	14	15
Maximum Solar Heat Gain Coefficient (SHGC)	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Maximum total area	14%	14%	14%	16%	14%	14%	14%	16%	16%	14%	16%
Maximum West facing area	NR	NR	5%	NR	NR	5%	5%	5%	5%	5%	5%

Package D																
Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Maximum Solar Heat Gain Coefficient (SHGC)	NR	0.40	NR	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.35	NR
Maximum total area	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Maximum West facing area	NR	5%	NR	5%	NR	NR	5%	5%	5%	5%	5%	5%	5%	5%	5%	NR

Package E																
Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Maximum Solar Heat Gain Coefficient (SHGC)	NR	0.40	0.40	0.25	0.40	0.40	0.25	0.40	0.40	0.40	0.25	0.25	0.30	0.25	0.25	NR
Maximum total area	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Maximum West facing area	NR	5%	NR	5%	NR	NR	5%	5%	5%	5%	5%	5%	5%	5%	5%	NR

Window Area

§101(b)

§151(f)3C

§151(e)

With the prescriptive requirements of Package D and E, window area is limited to a maximum of 20 percent of the conditioned floor area in all climate zones. In Package C the maximum is 14% in climate zone 1, 3, 4, 6-9, 14, and 16 and 16% in climate zone 2, 5, 10-13 and 15.   Package C, D and E in climate zones 2, 4, and 7 through 15, the window area facing west is limited to a maximum of 5 percent of the conditioned floor area.

The west-facing area requirement is intended to reduce peak demand, since west-facing windows have more solar gain during the peak cooling period and contribute more to the peak cooling load.

Rules for Doors that include Glass Areas

§116

The following rules apply to doors that have glass areas embedded in them.

1. Any door that is more than one-half glass is a fenestration product and must comply with the mandatory and prescriptive measures and other Standards requirements for fenestration products.

2. In the prescriptive approach, doors with less than 50 percent glass area, the U-factor and SHGC shall be based on either the NFRC values for the entire door including glass area, or use default values in Table 116-A or Table 116-B from the Standards. The opaque part of the door is ignored in the prescriptive approach. In the prescriptive approach, the glass area of the door is, calculated as the sum of all glass surfaces plus 2 inches on all sides of the glass (to account for a frame).
3. In the performance approach, for doors with less than 50 percent glass area, the U-factor shall be based on either the NFRC values for the entire door including glass area, or a default U-factor of 0.50 for the opaque portion. The glass area of the door shall be calculated as the sum of all glass surfaces plus 2 inches on all sides of the glass (to account for the frame); the opaque area of the door shall be considered the total door area minus this calculated glass area. If the default U-factor is used for the opaque portion, then the glass area shall be modeled under the rules for fenestration. Doors with 50 percent or more glass area shall be modeled under the rules for fenestrations using the total area of the door.

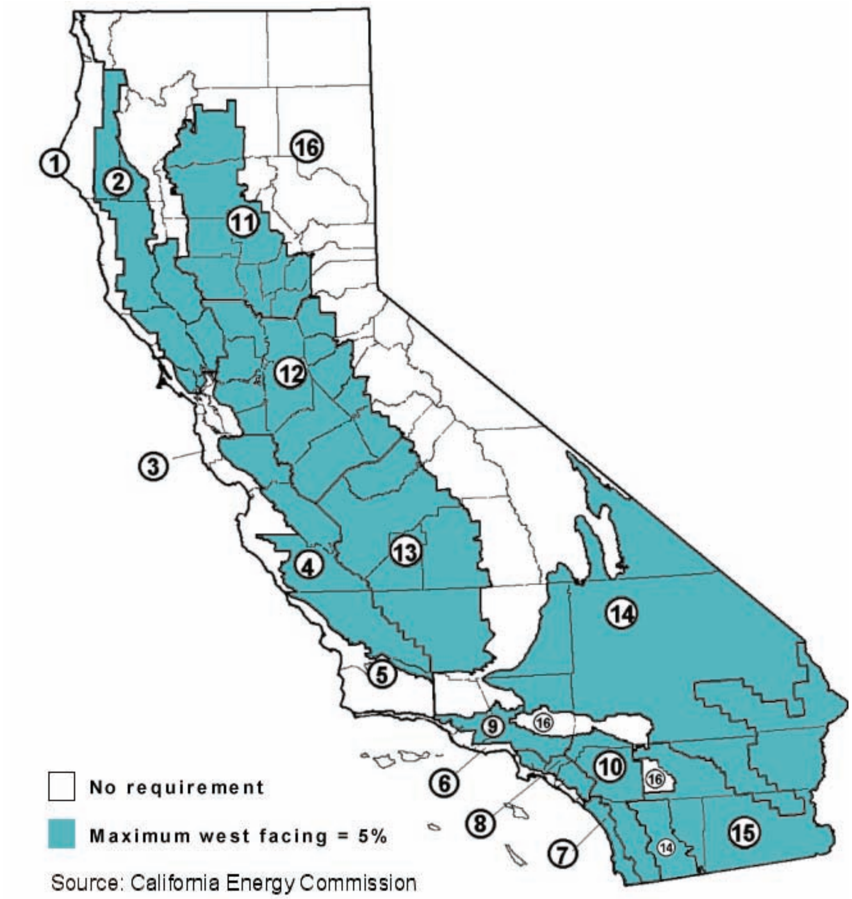


Figure 3-3 – Package C, D and E Prescriptive West-Facing Window Area Limits by Climate Zone

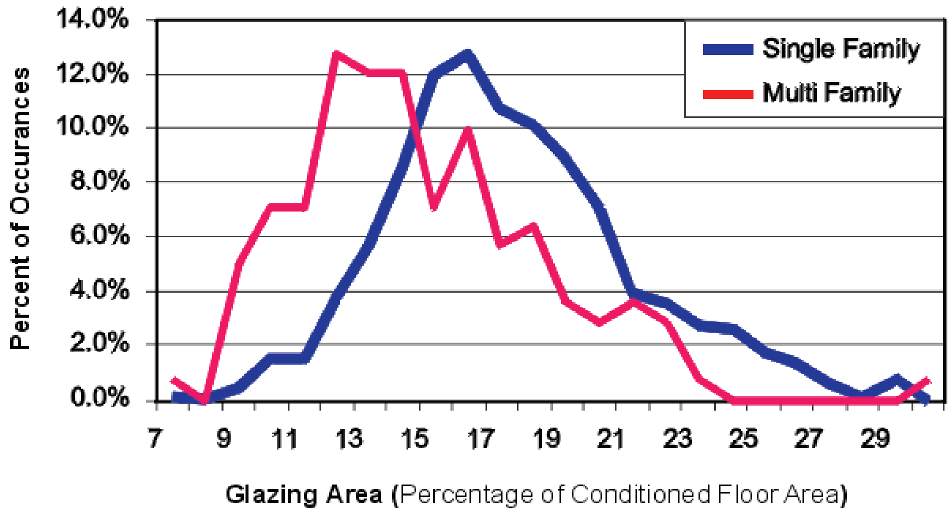
3.2.4 Compliance Options

While the prescriptive requirements and mandatory measures establish a minimum level of performance, the opportunities to exceed the requirements of the Standards are considerable. Some of these compliance options are discussed in this section. Those compliance options that are recognized for credit through the performance method are called compliance options. Most of the compliance options discussed in this section may be used only with the performance approach, but a few such as exterior shading devices and south facing overhangs may be used to comply with the prescriptive requirements.

Fenestration Area

With the 2008 update to the Standards, no credit is offered through the performance approach for reducing fenestration area below the maximum allowed 20 percent of the conditioned floor area (CFA).

Data show that the average window area in single family homes is about 17.3 percent of the CFA. In multifamily buildings, the average window area is about 14.5 percent of the conditioned floor area. While these are averages, the variations are considerable as shown in Figure 3-4. The reason that some houses have small fenestration areas and some have large areas, for the most part, has little to do with considerations of energy efficiency. Multifamily buildings have less window area as a percentage of the floor area because the overall floor areas are typically larger, and more space is located in the middle of the building away from fenestration. They also have less exterior wall area per CFA. Larger window areas are desirable for many reasons including letting in natural light and allowing scenic views.



(Source: Residential New Construction Database)

Figure 3-4 – Glass Area in Single Family and Multifamily Residence

Based on data shown in Figure 3-4, and as a matter of policy, the Energy Commission made fenestration area less than or equal to 20 percent a neutral variable in the performance approach with the 2005 update and there is no change in this regard in the 2008 update. The Commission recognizes that area and orientation can have a big impact on energy use, but because these are so variable in buildings, the Commission does not want the energy efficiency of other building components to be eroded in buildings that have small windows because of non-energy reasons.

While there is no credit for window area less than 20 percent of CFA, there is a penalty for buildings that have a window area that exceeds 20 percent of CFA. Such buildings are permitted only with the performance approach, where the standard design has a window area equal to the proposed design (up to 20 percent of the conditioned floor area), and the glass area in the standard design is uniformly distributed among cardinal orientations. The proposed design, on the other hand, has the exact proposed glass area and orientation.

Orientation

Window and skylight orientation has a huge impact on both energy use and peak electric demand. Orientation is a compliance option that is recognized in the performance approach, since the standard design has windows uniformly distributed on the north, south, east, and west sides of the building.

With the 2005 update and continuing under the 2008 update, the currency used to compare whole building performance is TDV energy. With TDV energy, savings during peak periods are worth more than savings at non-peak times. Window and skylight orientation was always an important feature and one for which the Standards have always offered a credit. The change to TDV makes window orientation even more important in the context of compliance.

Improved Window Performance

With the 2008 update, the U-factor has been reduced to 0.40 in all climate zones in Package D. This means there is less credit available for installing high performance windows that could be traded off or be used to avoid other measures, such as duct sealing and verification. However, choosing high performance windows that perform better than the prescriptive requirements can still earn significant credit through the performance method. In air conditioning climates, choosing a window with an SHGC lower than 0.40 will reduce the cooling loads compared to the standard design.

The magnitude of the impact will vary by climate zone; in mild coastal climates the benefit from reducing window U-factor will be smaller than in cold mountain climates. Computer compliance programs can be a useful tool to compare the impact of different windows and can help the designer determine when an investment in better windows is worthwhile.

Several factors affect window performance. For windows with NFRC ratings, these performance features are accounted for in the U-factor and SHGC ratings:

- Frame materials, design, and configuration (including cross-sectional characteristics). Fenestration is usually framed in wood, aluminum, vinyl, or composites of these. Frame materials such as wood and vinyl are better insulators than metal. Some aluminum-framed units have thermal breaks that reduce the conductive heat transfer through the framing element as compared with similar units that have no such conductive thermal barriers.
- Number of panes of glazing, coatings, and fill gases. Double-glazing offers opportunities for improving performance beyond the dimension of the air space between panes. For example, special materials that reduce emissivity of the surfaces facing the air space, including low-e or other coatings, improve the thermal performance of fenestration products. Fill gases other than dry air such as, carbon dioxide, argon, or krypton – also improve thermal performance.
- Gap width (i.e., the distance between panes).
- Window type (i.e., casement versus double hung).
- Spacer material (i.e., the type of material separating multiple panes of glass).

Fixed Shading Devices

Shading of windows is also an important compliance option. Overhangs or sidefins that are attached to the building or shading from the building itself are compliance options for which credit is offered through the performance approach. However, no credit is offered for shading from trees, adjacent buildings, or terrain.

Shading devices for which there is credit are those that are a part of the building design. For these, the designer and the builder have control over the measure and can assure that it will be constructed correctly and will perform properly. Non-credit devices are those that the designer has little or no control over, such as the height of a neighboring house or tree.

Windows that face south can be effectively shaded by overhangs positioned above the window. The ideal overhang is one that provides shade during the months when the building is likely to be in an air conditioning mode and allows direct solar gains in the heating months. This can be achieved because during the summer the sun is high as it passes over the south side, while in the winter it is low enabling solar radiation to pass beneath the overhang. Due to the potential effectiveness of south-facing overhangs, a prescriptive compliance option is offered. See the following section for details.

Shading is much more difficult on the east and west sides of the house (see Figure 3-5). When the sun strikes these façades it is fairly low in the sky, making overhangs ineffective. Vertical fins can be effective, but they degrade the quality of the view from the window and limit the natural light that can enter. In cooling climates, the best approach is to minimize windows that face east and west. Landscaping features can be considered to increase comfort but cannot be used for compliance credit.

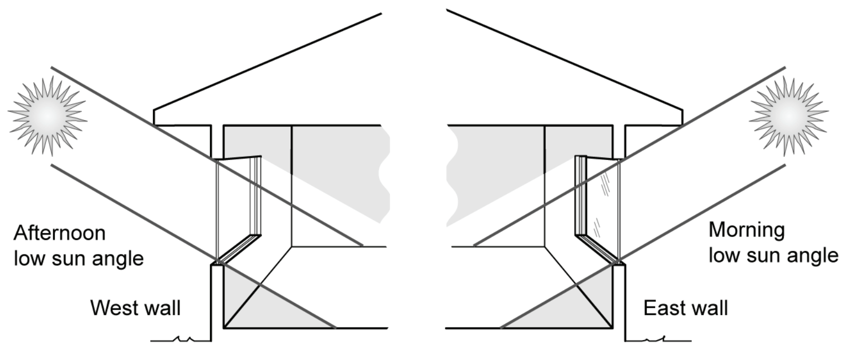


Figure 3-5 – Difficulty of Shading East- and West-Facing Windows

Prescriptive Compliance Using South-Facing Overhangs

A south-facing overhang may be used to meet the prescriptive SHGC criteria in the cooling climates. To qualify, the south overhang must be sized to completely shade the window at solar noon on August 21 and to allow the window to be substantially exposed to solar gains at solar noon on December 21. The minimum and maximum overhang depths that meet these criteria are illustrated in Figure 3-6. It is important to note that windows that do not face directly south will require larger overhangs for complete shading.

Credit is also offered for south facing overhangs with the performance method, but in this case the specific dimensions of the overhang are entered into a qualifying computer program and the benefit of the overhang is calculated for each hour of the day or sun angle. With the performance method, credit is not limited to south facing overhangs, although they are still most effective on this orientation.

When a south facing overhang is used for compliance, it must be shown on the plans.

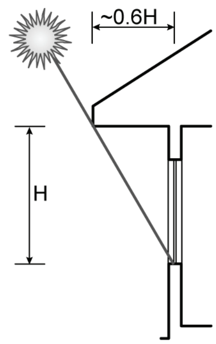
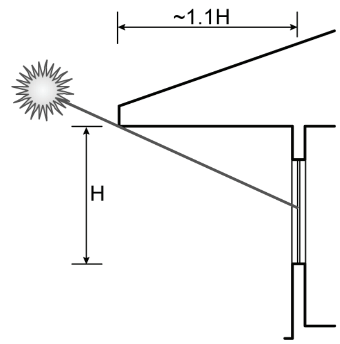
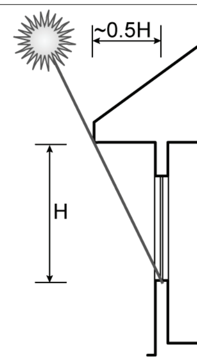
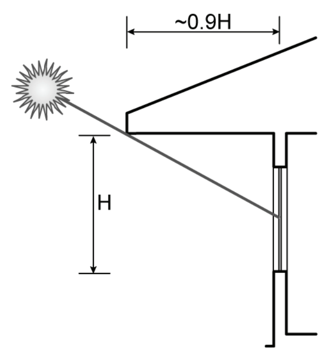
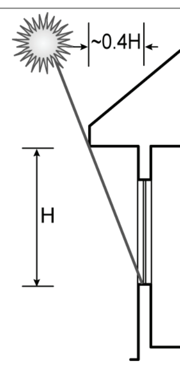
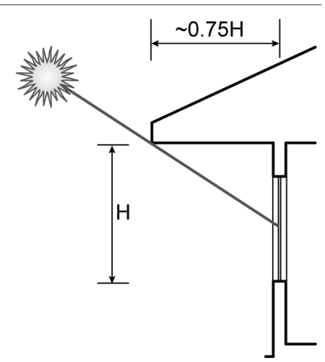
Location/Latitude	Minimum Depth (Noon August 21st)	Maximum Depth (Noon December 21st)
Redding Lat. ~ 41˚		
Fresno Lat. ~ 37˚		
San Diego Lat. ~ 33˚		

Figure 3-6 – South-Facing Overhang Dimensions for Prescriptive Compliance

Exterior Shading Devices

The prescriptive Standards require fenestration products with an SHGC of 0.40 or lower in climate zones 2, and 4 through 15. However, a fenestration product with an SHGC greater than 0.40 may be used with the prescriptive requirements if a qualifying exterior shading device is used. Qualifying exterior devices and their SHGC values are shown in Table 3-5. These include woven sunscreens as well as perforated metal sunscreens. As shown in the table, these devices transmit between 13 percent and 30 percent of the sun that strikes them.

When exterior shading devices are used, the SHGC requirements of prescriptive Package D may be met for all climate zones without calculations. Any exterior shading device other than bug screens listed in Table 3-5 will achieve compliance when used in combination with any allowed fenestration product.

For compliance credit, exterior shading devices must be permanently attached with fasteners that require additional tools to remove, as opposed to clips, hooks, latches, snaps, or ties. Exterior shading devices on windows or skylights that are prohibited by life-safety codes from being permanently attached for emergency egress reasons are exempt from this requirement.

Operable shading devices such as shutters, vertical roller shades or drop arm/combination awnings may be used as long as they are permanently attached to the building. Exterior shades on windows or skylights that are prohibited by life-safety codes from being permanently attached for emergency egress reasons are exempt from this requirement.

The SHGC of the window in combination with an exterior device is given by the following:

Equation[1]: $SHGC_{combined} = (0.2875 \times SHGC_{max} + 0.75) \times SHGC_{min}$

All windows are assumed to have an insect screen and this is the default condition against which other window/exterior shading device combinations are compared. The standard case is a window with an SHGC of 0.40 and an insect screen with an SHGC of 0.76 (see Table 3-5). For this default case, the SHGC of the window is the $SHGC_{min}$, and the SHGC of the exterior sunscreen is $SHGC_{max}$. Working through the math on WS-3R, $SHGC_{combined}$ is 0.3874. This means that any combination of window SHGC and exterior SHGC that results in an $SHGC_{combined}$ of 0.3874 or less complies with the prescriptive requirements.

All of the qualifying shading devices (other than the default) have an SHGC of 0.30 or lower. Combining this with the SHGC of any window will always result in an $SHGC_{combined}$ which is significantly lower than the prescriptive criterion of 0.40. This method of combining the SHGC of the window with the SHGC of the exterior shading device is also used with the whole building performance approach.

Compliance WS-3R is used to calculate the combined SHGC of windows and exterior shading devices. When exterior shades are required for compliance, they must be listed on the CF-1R form and be documented on the plans.

[1] The equation can be found in the 2008 Residential Compliance Manual and it is included in WS-3R in Appendix A.

Table 3-5 – Qualifying Exterior Shades and Solar Heat Gain Coefficients

Exterior Shading Device	SHGC
Standard Bug (insect) Screen (default for windows)	0.76
Exterior Sunscreens with Weave 53 x 16/inch	0.30
Louvered Sunscreens w/Louvers as wide as Window Openings	0.27
Low Sun Angle Louvered Sunscreen	0.13
Vertical Roller Shades or Drop Arm/Combination Awnings [2]	0.13
Roll -down Blinds or Slats	0.13
None (for skylights only)	1.00

Interior Shading

There is no credit for interior shading devices, although they can be effective in reducing solar gains and should be considered by homeowners. The Energy Commission considers interior shades in the category of home furnishings and not a feature of the house that is provided by the builder. Draperies, blinds, shades, and other interior devices are therefore not offered credit toward compliance. While there is no compliance credit, a default standard shade is still considered in performance calculations so that estimates of energy use are more realistic, and tradeoffs against other measures are more equitable. A default interior shade is not modeled, however, with skylights.

Bay Windows

Bay windows are a special compliance case. Bay windows may either have a unit NFRC rating (i.e., the rating covers both the window and all opaque areas of the bay window), an NFRC rating for the window only, or no NRFC rating. Non-rated bay windows may or may not have factory-installed insulation.

For bay windows that come with an NFRC rating for the entire unit, compliance is determined based on the rough opening area of the entire unit, applying the NFRC U-factor and SHGC. If the unit U-factor and SHGC do not meet the package requirements, the project must show compliance using the performance approach.

Bay windows with no rating for the entire unit (where there are multiple windows that make up the bay) and with factory-installed or field-installed insulation must comply accounting for the performance characteristics of each component separately. Opaque portions of bay windows including roofs and floors, must be insulated to meet the wall insulation requirements of Package D (§150(c)3). For prescriptive compliance, the opaque portion must either meet the minimum insulation requirements of the Package D for the applicable climate zone or be included in a weighted average U-factor calculation of an overall opaque assembly that does meet the Package D requirements. For the windows, the U-factor and SHGC values may be determined either from an NFRC rating or by using default values. If the window U-factor and SHGC meet the package requirements, the bay window complies prescriptively (if overall building fenestration area meets prescriptive compliance requirements). Bay window fenestration area is based on each individual window in the bay window. If the bay window does not meet package requirements, the project must show compliance under the performance approach. Bay window fenestration area and orientation in the performance approach are based on each individual window in the bay window.

Natural Ventilation through Windows

Operable windows can be a source of "free" cooling. During periods when the outdoor temperature is lower than the desired indoor temperature and the indoor temperature is uncomfortably warm from solar gains through windows or from heat generated inside the house, windows may be opened for some or all of the cooling. Natural ventilation can reduce the need to run the air conditioner. Not only does natural ventilation save energy, but it can also provide better air quality inside the home.

In performance calculations, natural ventilation through windows is modeled. The default assumption is that the free ventilation area is 10 percent of the total window area and the height difference between the inlet and the outlet is 2 ft for single-story buildings and 8 ft for two- and three-story buildings. Credit is offered for design solutions that result in better natural ventilation. Credit is offered through the performance method for buildings with a larger percent of casement windows (larger free area than sliders) and for windows that are positioned so that the height difference between inlets and outlets is greater.

Noise is a major deterrent to opening windows for ventilation or cooling. When a house is designed, neighboring noise sources should be identified, and the design of the house should be modified to soften the effects. Exterior mass walls are often used to reduce freeway or roadway noise. The location and design of windows should also be considered. Dusty conditions are also deterrents to the use of operable windows for ventilation.

Operable windows can be a source of ventilation air useful for improving indoor air quality by dilution of indoor air contaminants and moisture. When building envelopes are sealed to reduce infiltration, air exchange with the outside air is reduced which increases the need for a mechanical means of bringing in outside air.

Energy Commission sponsored research in California homes has shown that a significant number of home occupants do not regularly open their windows for ventilation. Starting with the 2008 update, it is mandatory to meet the requirements of ASHRAE Standard 62.2 which include mechanical ventilation and minimum openable window area requirements. This mandatory measure is discussed in greater detail in Section 3.5. Also see Section 4.6 for mechanical ventilation requirements.

3.2.5 Compliance and Enforcement

The compliance and enforcement process for fenestration products is basically for ensuring that the data from one set of documents matches data in another, and that with the specified fenestration performance, the building complies with the Standards.

Compliance Documentation

The person responsible for the compliance documentation must verify that data used in the calculations and entered on the compliance forms is reasonable. If data does not match the construction documents (plans) or if the plans are still under development, the compliance documentation author should make sure that the person preparing the plans understands what U-factor and SHGC are required for the fenestration products.

When performing compliance calculations and preparing documentation, the compliance author should consult manufacturers' published data (web site) found in the Certified Products Directory of fenestration products that contains the certified U-factor ratings. The directory is available at http://www.nfrc.org.

If the exact make and model number of the fenestration products to be installed are not known, there are a few options:

1. Look up the U-factors for a number of products most likely to be installed and use the highest value of those products in the compliance calculations. Whichever fenestration product is then installed will comply with the U-factor used in the calculation. Follow a similar procedure for SHGC.
2. Specify a particular product and state "or equivalent." In this approach, the builder or installer must understand that the U-factor and SHGC of the installed product must match, or be less than, the U-factor and SHGC specified in the compliance documentation.
3. Use the appropriate default U-factor from Standards Table 116-A and default SHGC from Standards Table 116-B; however, this approach has disadvantages:
    a. There is no guarantee that a selected product will have the same or better performance than the U-factor assigned to that generic type; and,
    b. The compliance benefits of installing a high efficiency window will be lost.

Plan Checking

The plans examiner verifies that the fenestration product U-factors and SHGCs used on the compliance documents match those on the plans. The plans examiner can also verify that special shading devices such as exterior sunscreens are documented in the special features section of the Certificate of Compliance (CF-1R) so this information will be available for the field inspector.

Construction

The fenestration product installer needs to understand the required U-factors and product SHGC values for the specific project, based on the compliance documentation such as the CF-1R. The installer should check the documentation to ensure that the products have the temporary label with information documenting that the window meets the compliance requirements.

NFRC labels include U-factor and SHGC data for residential (and nonresidential) windows. Verify that the residential data complies. The temporary label must remain on the product until the field inspector has inspected it.

The fenestration contractor must complete the Installation Certificate (CF-6R-ENV-01).

Field Inspection

The field inspector should verify that the windows and other fenestration products installed have performance characteristics that are documented on the temporary NFRC labels and that comply with the U-factor and SHGC used in the compliance documentation, including the CF-6R-ENV-01. All fenestration products must have a temporary label indicating U-factor, SHGC, and air infiltration rate (only field-fabricated products are exempt from labeling requirements).

The field inspector must compare the actual installed glass area with the glass area indicated on the CF-6R-ENV-01 and with the maximum allowed glass areas indicated on the CF-1R. If more glass is installed, then the appropriate action depends on the compliance approach. If the prescriptive method was used, the glass area must not exceed the prescriptive limit (20 percent of floor area and in some climates a separate 5 percent west-facing limit). If the performance approach was used, then the compliance calculations must be redone to demonstrate compliance with the higher glass area.

3.3 Insulation

This section of the building envelope chapter addresses the requirements for insulating the opaque portion of the building shell. Components of the building shell include the walls, the floor, and the roof or ceiling. Windows and doors are addressed in Section 3.2, Fenestration.

3.3.1 Insulation General Mandatory Measures

§118

A number of mandatory measures apply to insulation in general, and those are covered in this section:

- Insulating materials must be certified and labeled by the manufacturer.
- Urea formaldehyde foam insulation may be installed only in exterior side walls and with a four-mil-thick (0.1 mm) plastic polyethylene vapor barrier or equivalent plastic sheeting vapor barrier installed between the urea formaldehyde foam insulation and the interior space. Insulating materials installed in exposed applications must have a flame spread of 25 or less and a smoke development rating of 450 or less.

Other mandatory measures apply to specific applications, and they are covered in the sections on ceiling/roof insulation, wall insulation, floor insulation, and slab insulation.

Certification of Insulating Materials

§118(a)

The California Standards for Insulating Materials, which became effective on January 1, 1982, ensure that insulation sold or installed in the state performs according to the stated R-value and meets minimum quality, health and safety standards.

All materials which claim insulation thermal conductive performance for compliance must be certified by Department of Consumer Affairs, Bureau of Home Furnishing and Thermal Insulation that the insulation conductive thermal performance complies with the California Code of Regulations, Title 24, Part 12, Chapters 12-13, Article 3, and "Standards for Insulating Material." Builders may not install the types of insulating materials indicated in §118(a) unless the manufacturer is licensed to sell in California and the insulation product is certified under one of the categories of insulating materials covered by the Bureau of Home Furnishings. Builders and enforcement agencies should use the Department of Consumer Affair's *Consumer Guide and Directory of Certified Insulation Material* to check compliance. Enforcement agencies receive a copy of the current directory. If an insulating product is not listed in the most recent edition of the directory, or to purchase a directory, contact the Department of Consumer Affairs Thermal Insulation Program at (916) 574-2041.

Urea Formaldehyde Foam Insulation

§118(b)

Urea formaldehyde is restricted by Section 1553 of CBC Title 24, Part 12. If such products are certified, this is verification that the restrictions of Section 1553 were met. The restrictions in §118 also apply, which allow the use of urea formaldehyde foam insulation only if:

1. it is installed in exterior side walls; and
2. a four-mil-thick (0.1 mm) plastic polyethylene vapor barrier or equivalent plastic sheeting vapor barrier is installed between the urea formaldehyde foam insulation and the interior space in all applications.

Flame Spread Ratings

§118(c)

California Standards for Insulating Materials require that all exposed installations of faced mineral fiber and mineral aggregate insulations use fire retardant facings. Exposed installations are those where the insulation facings do not touch a ceiling, wall or floor surface, and faced batts on the underside of roofs with an air space between the ceiling and facing. These installations require insulation that has been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450.

Flame spread ratings and smoke development ratings are shown on the insulation or packaging material or may be obtained from the manufacturer.

3.3.2 Ceiling/Roof Insulation

Mandatory Measures

§118(d), §118(e), §150(a), §150(b)

These sections are also shown in Appendix B of this document.

The following mandatory measures apply specifically to roof and ceiling insulation:

1. If insulation is going to be installed in the attics of existing buildings, at least R-38 must be installed in climate zones 1 and 16 and at least R-30 in the other climate zones. Insulation in roof/ceiling constructions must be placed in direct contact with the infiltration barrier. In most cases the attic is ventilated and the infiltration barrier is the drywall ceiling; in this case, the insulation must lie directly on top of the ceiling.
2. Wood framed ceiling/roof construction assemblies must have at least R-19 insulation or a maximum U-factor of 0.051 based on 16 inch (40 cm) on center wood framed rafter roofs, as determined from the Reference Joint Appendix JA4. The equivalent U-factor is from Table 4.2.2, cell entry A5, which is R-19 insulation in a wood framed rafter roof.
3. Some areas of the ceiling/roof can fail to meet the mandatory minimum U-factor as long as other areas exceed the requirement and the weighted average U-factor for the overall ceiling/roof is 0.051 or less.
4. In new construction, the R-19 mandatory minimum level of insulation applies for the performance compliance method. Otherwise, the R-19 minimum is superseded by the prescriptive requirements, which call for either R-30, R-38, or R-49 depending on the climate zone and component package.
5. Metal-framed and ceiling/roof constructions other than wood framed must have a U factor of 0.051 or less in order to comply with the mandatory measures. If the insulation is not penetrated by framing, such as rigid insulation lain over a structural deck, then the rigid insulation can actually have a rated R-value of less than R-19, and the mandatory measures can be satisfied.

Example 3-11

Question

A computer method analysis shows that a new house requires R-30 ceiling insulation to comply using the performance approach, but the minimum mandatory insulation level for ceiling insulation is only R-19. Which insulation level should be used?

Answer

R-30. The higher insulation level must be installed for the building to comply. In some cases such as this, minimum mandatory measures are superseded by stricter compliance measures when using the performance approach.

Example 3-12

Question

A small addition to an existing house appears to comply using only R-15 ceiling insulation with the performance approach. Does this insulation level comply with the Standards?

Answer

No. R-15 would not be sufficient because the required minimum ceiling insulation level established by the mandatory measures is R-19. However, R-15 could be used in limited areas, as follows:

1. 16-inches on center framing with attic with the weighted average U-factor for the entire ceiling/roof less than 0.049.

2. 24-inches on center framing with attic with the weighted average U-factor for the entire ceiling/roof less than 0.048.

3. 16-inches on center rafter without attic with the weighted average U-factor for the entire ceiling/roof less than 0.051.

4. 24-inches on center rafter without attic with the weighted average U-factor for the entire ceiling/roof less than 0.049.

Prescriptive Insulation Requirements

§151(f)1A

There are three prescriptive compliance approaches: Component Package C, Component Package D, and Component Package E. The following paragraphs discuss Component Package D, as it is the basis for the performance calculation methods. The prescriptive Package D compliance method requires R-38 insulation in climate zones 1 and 11 through 16. R-30 insulation is required in the other climate zones. In addition, a radiant barrier is required in climate zones 2, 4 and 8 through 15; the climate zones where air conditioning is more common (see Figure 3-7).

There are two ways to meet the prescriptive insulation requirement. The first is to install R-30 or R-38 insulation in wood-framed construction. Wood-framed constructions include those in Tables 4.2.1 and 4.2.2 in Reference Joint Appendix JA4.

The other is to use a different roof assembly from Reference Joint Appendix JA4, including structural insulated panel systems (SIPS) and metal-framed roofs, as long as they have a U-factor less than that of a wood-framed attic (the choices from Table 4.2.1 in Reference Joint Appendix JA4). The U-factor criteria are 0.026 (Table 4.2.1, cell entry A9) in climate zones 1 and 11 through 16 (where R-38 is required) and 0.032 (Table 4.2.1, cell entry A8) in the other climate zones (where R-30 is required).

Note that R-30 or R-38 installed in a wood rafter construction (the choices from JA4 Table 4.2.2) are acceptable for complying with Component Package D and Package E, since they have the minimum required insulation, even though these have a U-factor higher than the U-factor criteria stated above.

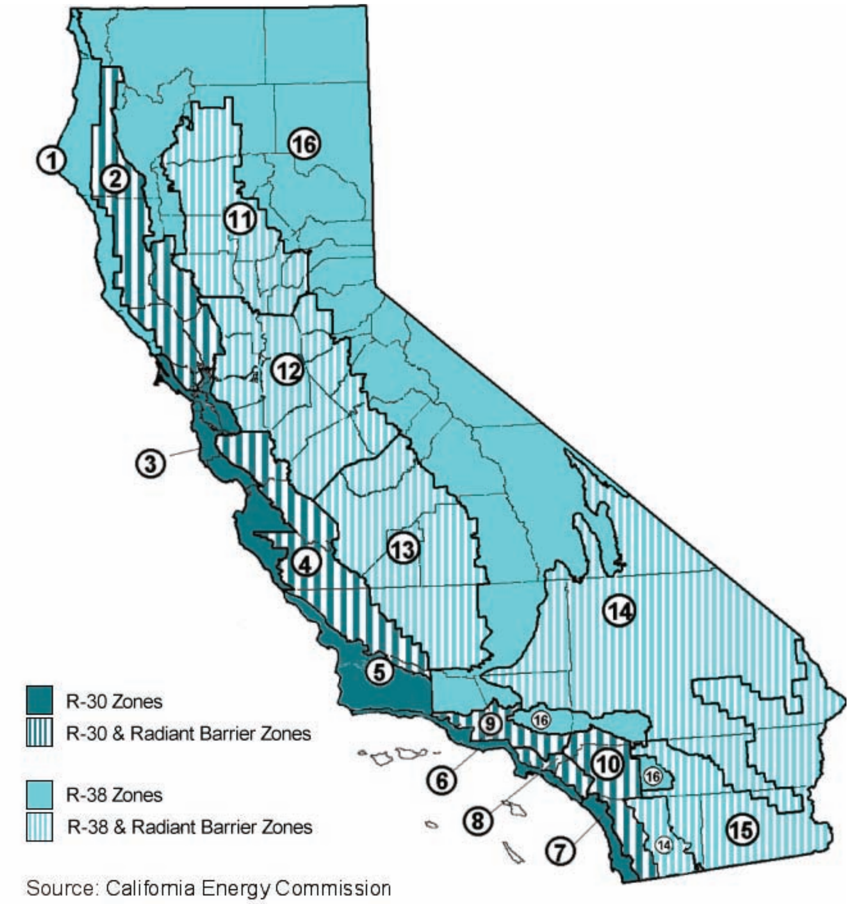


Figure 3-7 – Package D Prescriptive Ceiling/Roof Insulation Requirements

Construction Practice

Insulation Coverage

Ceiling insulation should extend far enough to the outside walls to cover the bottom chord of the truss. However, insulation should not block eave vents in attics because if the flow of air is blocked, moisture may build up in the attic and water vapor may condense on the underside of the roof. This can cause structural damage and reduce the insulation's effectiveness.

Insulation may be tapered near the eave, but it must be applied at a rate to cover the entire ceiling at the specified level. An elevated truss is not required but may be desirable. See Figure 3-8.

Loose Fill Insulation

§150(b) Loose Fill Insulation

Loose fill insulation must be blown in evenly, and insulation levels must be documented on the Installation Certificate (CF-6R). The insulation level can be verified by checking that the depth of insulation conforms to the manufacturer's coverage chart for achieving the required R-value. The insulation must also meet the manufacturer's specified minimum weight per ft² for the corresponding R-value. When installing loose fill insulation, the following guidelines should be followed:

1. For wood trusses that provide a flat ceiling and a sloped roof, the slope of the roof should be at about 4:12 or greater in order to provide adequate access for installing the insulation. Insulation thickness near the edge of the attic will be reduced with all standard trusses, but this is acceptable as long as the average thickness is adequate to meet the minimum insulation requirement.
2. If the ceiling is sloped (for instance, with scissor trusses), loose fill insulation can be used as long as the slope of the ceiling is no more than 4:12. If the ceiling slope is greater than 4:12, loose fill should be used only if the insulation manufacturer will certify the installation for the slope of the ceiling.
3. At the apex of the truss, a clearance of at least 30 inch should be provided to facilitate installation and inspection.

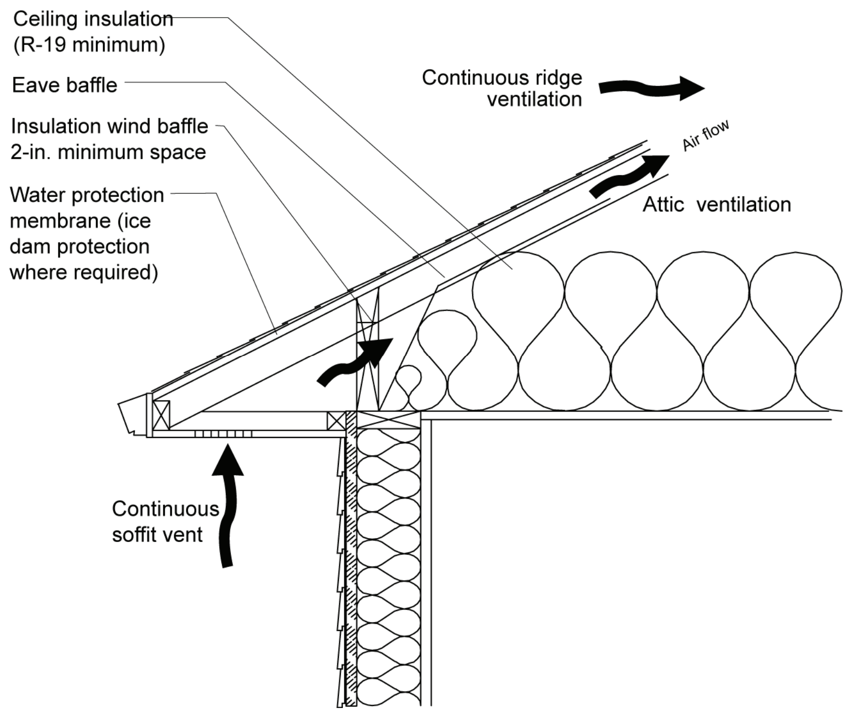
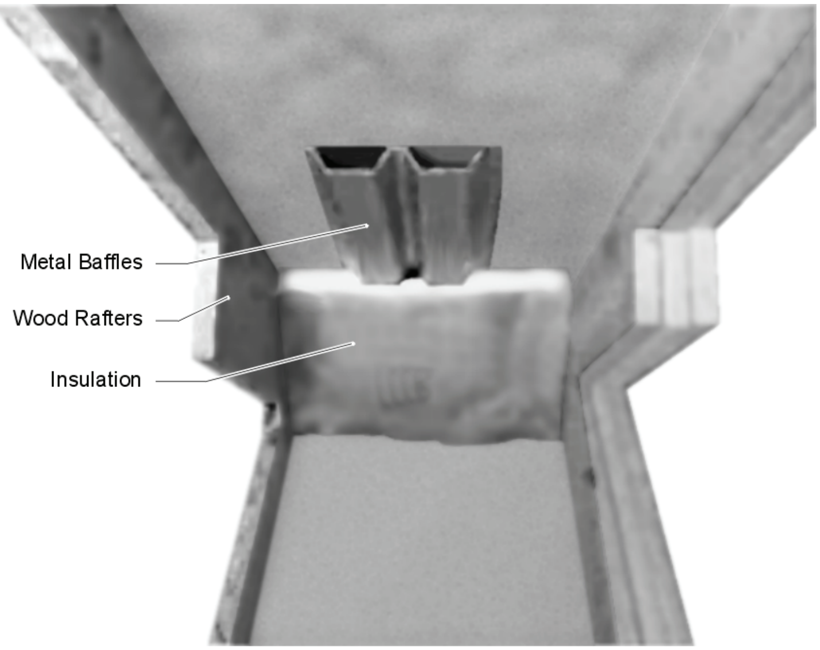


Figure 3-8 – Ceiling Insulation Construction Detail



Source: California Energy Commission

Figure 3-9 – Baffles at the Eave in Attics

Ventilation

Where ceiling insulation is installed next to eave or soffit vents, a rigid baffle should be installed at the top plate to direct ventilation air up and over the ceiling insulation. See Figure 3-9.The baffle should extend beyond the height of the ceiling insulation and should have sufficient clearance between the baffle and roof deck at the top. There are a number of acceptable methods for maintaining ventilation air, including pre-formed baffles made of either paper or plastic. In some cases, plywood baffles are used.

The CBC requires a minimum vent area of 1 ft² for each 150 ft² of attic floor area. This ratio may be reduced to 1 to 300 if a ceiling vapor retarder is present or if high (for example, ridge or gable vents) and low (soffit vents) attic ventilation is used.

When part of the vent area is blocked by meshes or louvers, the net free area of the vent must be considered when meeting ventilation requirements.

Wood Rafter Constructions

Ventilating solid rafter spaces is more difficult than ventilating attics because each framing cavity requires its own vent openings. However, the requirement for ventilation is at the discretion of the local building official. It is common practice with cellulose insulation, for instance, to completely fill the cavity so that there is no ventilation at all. Also, if spray polyurethane foam is used, it is applied to the underside of the roof deck leaving no ventilation space. With batt insulation, it is possible to ventilate above the insulation using eave baffles, ridge vents, and careful installation.

Light Fixtures and Recessed Equipment

§150(k)5

Luminaires recessed in insulated ceilings can create thermal bridging through the insulation. Not only does this degrade the performance of the ceiling assembly, but it can also permit condensation on a cold surface of the luminaire if exposed to moist air, as in a bathroom.

For these reasons, luminaires recessed in insulated ceilings must meet three requirements:

1. They must be approved for zero clearance insulation cover (IC) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Conference of Building Officials. This enables insulation to be packed in direct contact with the luminaire. (See Figure 3-10).
2. The luminaire must have a label certifying air tight (AT) construction. Air tight construction means that leakage through the luminaire will not exceed 2.0 cfm when exposed to a 75 Pa pressure difference, when tested in accordance with ASTM E283.
3. The luminaire must be sealed with a gasket or caulk between the housing and ceiling. For more information see Section 6.10 of this manual.

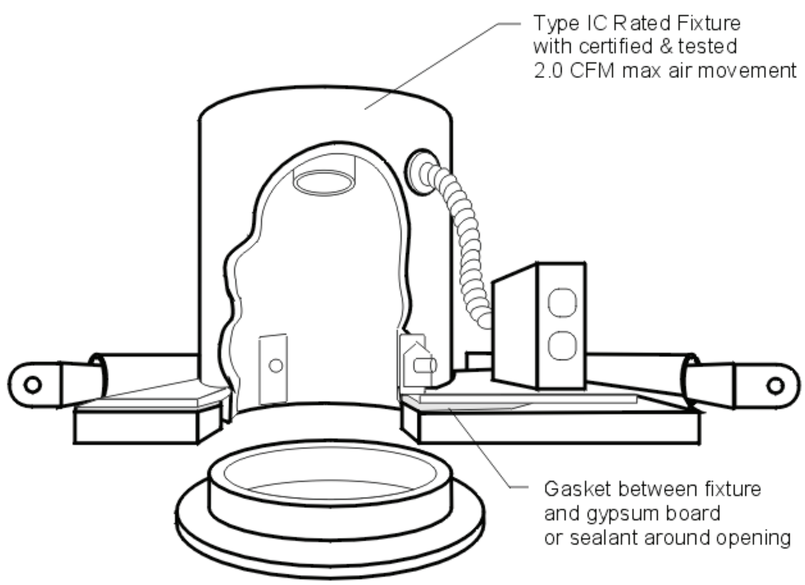


Figure 3-10 – IC-Rated Light Fixture

3.3.3 Radiant Barriers

Radiant Barrier Requirements

§151(f)2

The prescriptive requirements call for a radiant barrier in climate zones with significant cooling loads (2, 4, and 8 through 15). The radiant barrier is a reflective material that reduces radiant heat transfer caused by solar heat gain in the roof. Radiant barriers reduce the radiant gain to air distribution ducts and insulation located below the radiant barrier. In the performance approach, radiant barriers are modeled as separate adjustments to the heating U-factor and the cooling U-factor. The duct efficiency is also affected by the presence of a radiant barrier, with the performance approach.

Radiant Barrier Construction Practice

To qualify, a radiant barrier must have an emittance of 0.05 or less. The product must be tested according to ASTM C-1371-98 or ASTM E408-71(2002) and must be certified by the Department of Consumer Affairs[2]. Radiant barriers must also meet installation criteria as specified in Residential Appendices RA4.2.2 (Section RA4.2.2 is also reproduced in Appendix D of this document).

The most common way of meeting the radiant barrier requirement is to use roof sheathing that has a radiant barrier bonded to it in the factory. Oriented strand board (OSB) is the most common material available with a factory-applied radiant barrier. The sheathing is installed with the radiant barrier (shiny side) facing down toward the attic space. Alternatively, a radiant barrier material that meets the same ASTM test and moisture perforation requirements that apply to factory-laminated foil can be field-laminated. Field lamination must use a secure mechanical means of holding the foil to the bottom of the roof decking such as staples or nails that do not penetrate all the way through the roof deck material.

Other acceptable methods are to drape a foil type radiant barrier over the top of the top chords before the sheathing is installed, stapling the radiant barrier between the top chords after the sheathing is installed, and stapling the radiant barrier to the underside of the truss/rafters (top chord). For these installation methods, the foil must be installed with spacing requirements as described in Residential Appendices RA4.2.2. The minimum spacing requirements do not apply to this installation since it is considered a “laminated” system.

Installation of radiant barriers is somewhat more challenging in the case of closed rafter spaces when sheathing is installed that does not include a laminated foil. Foil may be field-laminated after the sheathing has been installed by “laminating”

[2] Certification of radiant barriers is required by CCR, Title 24, Part 12, Chapter 12-13, Standards for Insulating Material.

the foil as described above to the roof sheathing between framing members. This construction type is described in the Residential Appendices RA 4.2.2.

See Figure 3-11 for drawings of radiant barrier installation methods.

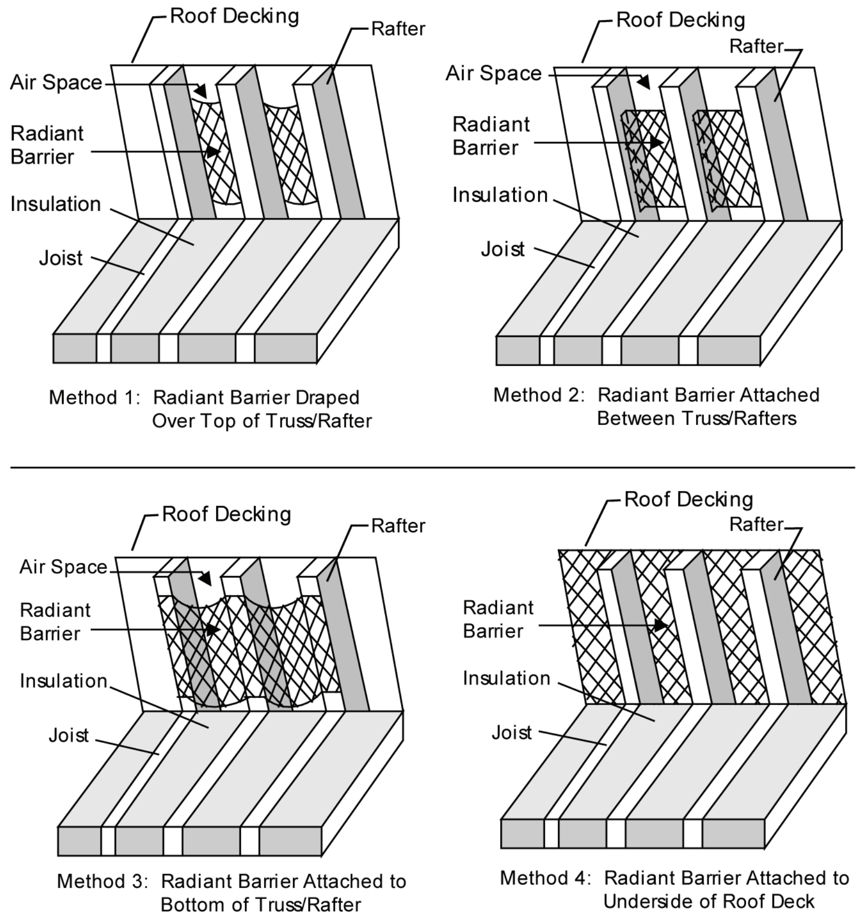


Figure 3-11 – Methods of Installation for Radiant Barriers

3.3.4 Wall Insulation

Mandatory Measures

§150(c)

The mandatory measures require that wood-framed walls above grade have at least R-13 insulation installed in the cavities between the framing members. However, the prescriptive measures for Component Package C and Package E require more insulation than the minimum requirements in all climate zones. Likewise, Component Package D requires more insulation than the minimum requirements in climate zones 1 and 11 through 16.

Wall constructions with insulation that is not penetrated by framing members, or with metal framing, comply with this mandatory measure if they have a U-factor lower than 0.102, which is the U-factor of a wood-framed wall with R-13 insulation. Cell entry A3 in Table 4.3.1 in Reference Joint Appendix JA4 is the basis for the U-factor criterion.

Insulation may be of greater insulating value in certain areas of the wall and of lesser insulating value in other areas of the wall provided that the area-weighted U- factor does not exceed 0.102 to show equivalence to an R-13 wall.

There are several cases where the mandatory measures for wall insulation do not apply or apply in a special way. These include the following:

1. The mandatory measures apply to framed foundation walls of heated basements or heated crawl spaces that are located above grade, but not to the portion that is located below grade.
2. Existing wood-framed walls of an addition that are already insulated with R-11 insulation need not comply with the mandatory R-13 wall insulation, but this exception applies only with the performance method. See Exception 1 to §152(a).
3. Rim joists between the stories of a multi-story building are deemed to comply with these mandatory measures if they have R-13 insulation installed on the inside of the rim joist and carefully fitted between the joists.

Prescriptive Requirements – Framed Walls

§151(f)1A

The Package D and Package E prescriptive requirements (Standards Table 151-C and Table 151-D, also in Figure 3-12 below and Appendix B of this document) call for R-19 wall insulation in climate zones 11 through 13 and R-21 wall insulation in climate zones 1 and 14 through 16. R-13 insulation is required in other climate zones. The Package C requirements call for significantly more insulation (see Standards Table 151-B, also in Appendix B of this document).

Wood-framed walls may comply by specifying and installing the minimum R-value indicated. For metal-framed walls, or as an alternative to meeting the installed R-value in wood-framed walls, the designer may choose any wall construction from Reference Joint Appendix JA4 that has a U-factor equal to or less than the U-factor of a wood-framed wall with the required insulation.

For climates where R-13 is required, the maximum U-factor is 0.102 (Reference Joint Appendix JA4 Table 4.3.1, cell entry A3). For climates where R-19 is required, the maximum U-factor is 0.074 (JA4 Table 4.3.1, cell entry A5). In climates where R-21 is required, the maximum U-factor is 0.069 (JA4 Table 4.3.1, cell entry A6).

Metal-framed assemblies will require rigid insulation in order to meet the maximum U- factor criteria. U-factors for metal-framed walls are given in Reference Joint Appendix JA4 Table 4.3.4.

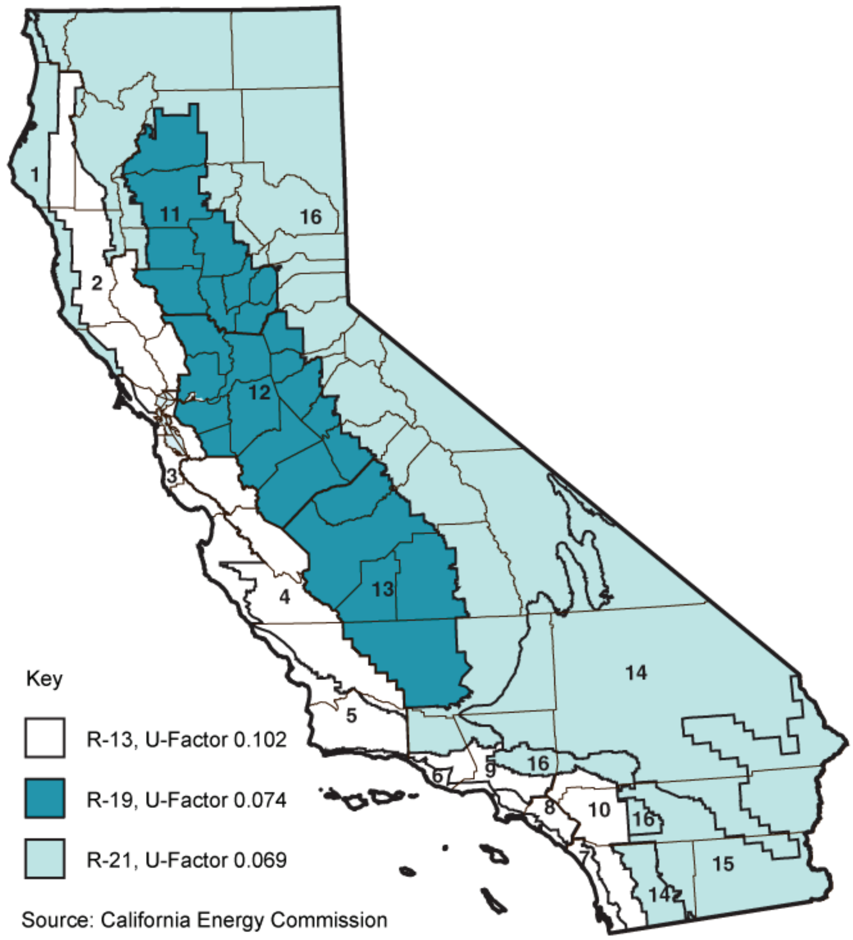


Figure 3-12 – Package D Wall Requirements by Climate Zone

Prescriptive Requirements – Mass Walls

§151(f)1A
§151(f)
These sections are also shown in Appendix B of this document.

The prescriptive requirements have separate criteria for heavy mass walls. While the Standards recognize both heavy mass and light mass walls, separate criteria are presented only for heavy mass walls and only for Package D and Package E. Heavy mass walls are those that weigh more than 40 lb/ft². Where the package indicates "NA" for a light mass wall the assembly must comply with 0.102 U-factor for climate zones that require R-13 for wood-framed walls, or 0.074 for where R-19 is required, or 0.069 where R-21 is required the. The "NA" applies to both heavy and light mass walls for Package C and light mass walls for Package D and Package E.

The R-value listed in Standards Table 151-C and Table 151-D (also in Appendix B of this document) for heavy mass walls is the minimum R-value for the entire wall assembly, including insulation and both interior and exterior air films. Heavy mass walls require R-2.44 in climates 2 through 10 and R-4.76 in the other climates. Tables 4.3.5, 4.3.6 and 4.3.7 from Reference Joint Appendix JA4 have the thermal properties of hollow unit masonry, solid core masonry, and concrete walls. Choices from these tables that have a heat capacity (HC) greater than or equal to 8.0 have a density greater than 40 lb/ft³ and qualify as heavy mass walls.[3]

Concrete Mass and Furred Walls

To determine the total R-value of a heavy mass wall, the U-factor from Reference Joint Appendix JA4 Table 4.3.5, 4.3.6 or other masonry tables is added to an insulation layer selected from Reference Joint Appendix JA4 Table 4.3.13. When the prescriptive requirements are used, the insulation must be installed integral with or on the exterior of the heavy mass wall. To accurately calculate the effective overall efficiency of the concrete wall and furring the Prescriptive CF-1R form can calculate the U-factor by using the Insulation Values for Opaque Surface table.

Figure 3-13 – Brick wall with furring details

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[3] This assumes a specific heat of 0.2 of the mass.

The walls addressed in the Properties of Solid Unit Masonry and Solid Concrete Walls tables in the Reference Joint Appendix JA4 tables are rarely used in residential construction, but are common in some types of nonresidential construction. For residential construction, the Prescriptive CF-1R, CF-1R-ADD and CF-1R-ALT can calculate complex wall systems to include furred strip walls.

A four step process is required to calculate the effective U-factor of a furred wall;

1. Select one of the concrete or masonry walls tables and select a U-factor; and
2. Select the appropriate Effective R-value for Interior or Exterior Insulation Layers in Table 4.3.13; and
3. Fill out the CF-1R Insulation *Values for Opaque Surface* table columns. To achieve the Proposed Assembly U-factor or R-value column, first the *Furring Strips Construction Table for Mass Walls Only* table needs to be filled out; and
4. Calculate the Final Assembly R-value and carry the value to back to the *Insulation Values for Opaque Surface Details* table. Compare the R-value, it must be equal to or greater than the mass standard R-value from Energy Standards Prescriptive Table 151-C or D.

Construction Practice

1. Because it is difficult to inspect wall insulation behind tub/shower enclosures after the enclosures are installed, insulation of these wall sections should be inspected during the framing inspection.
2. Batt insulation should fill the wall cavity evenly. If Kraft or foil-faced insulation is used, it should be installed per manufacturer recommendations to minimize air leakage and avoid sagging of the insulation.
3. Wall insulation should extend into the perimeter floor joist (rim joist) cavities along the same plane as the wall.
4. If a vapor barrier is required, it must be installed on the conditioned space side of the framing.

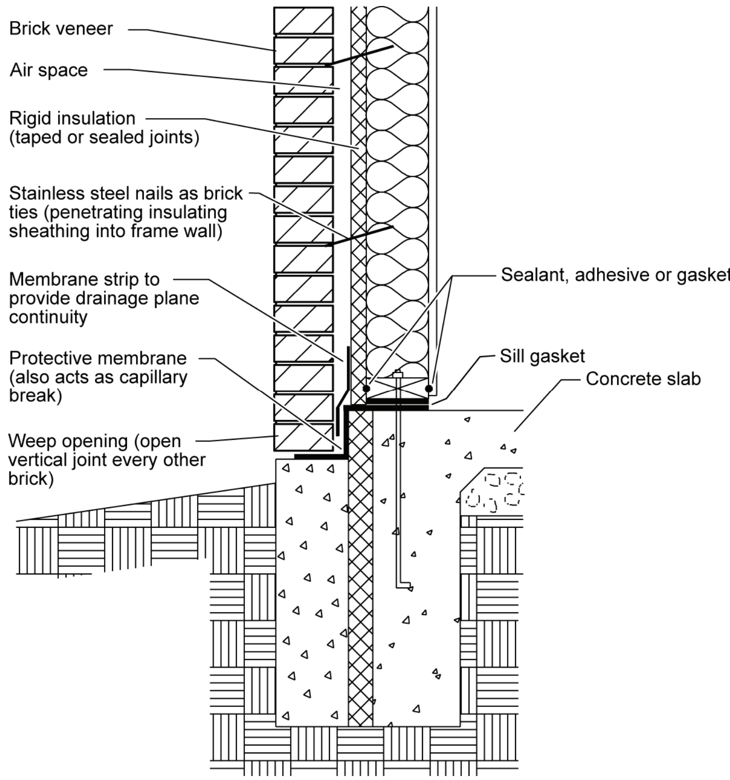


Figure 3-14 – Brick Wall Construction Details

Wood-Framed Wall with Brick Veneer, Mandatory Minimum R-13 Insulation

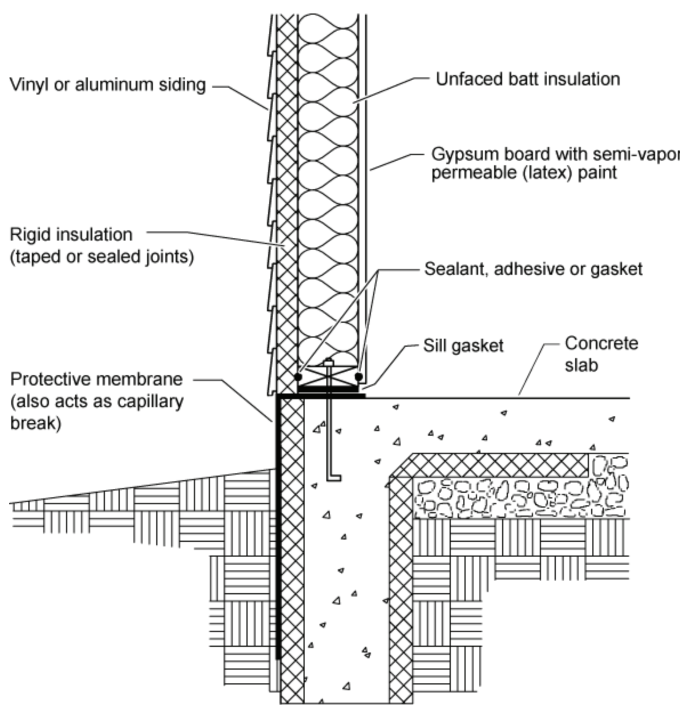


Figure 3-15 – Wall Construction Detail

Wood-Framed Wall with Vinyl or Aluminum Siding, Mandatory Minimum R-13 Insulation

Example 3-13

Question

Do new residential buildings or additions consisting of block walls (for example, converting a garage into living space) have to comply with the R-13 minimum wall insulation requirement? If not, what insulation R-value do they need?

Answer

No, the mandatory wall insulation requirement for R-13 applies to frame walls only. The amount of insulation needed, if any, will vary depending on the compliance approach selected. Performance compliance may not require any additional insulation if compliance can be achieved without insulation in that space. Prescriptive compliance may require some level of insulation, depending on the climate zone, package selected, and whether the walls are light (block) or heavy mass. Use Reference Joint Appendix JA4 to determine the R-value of the mass wall alone. If additional insulation is required, it must be integral with the wall or installed on the outside of the mass wall.

3.3.5 Floor Insulation

Mandatory Measures

§150(d)

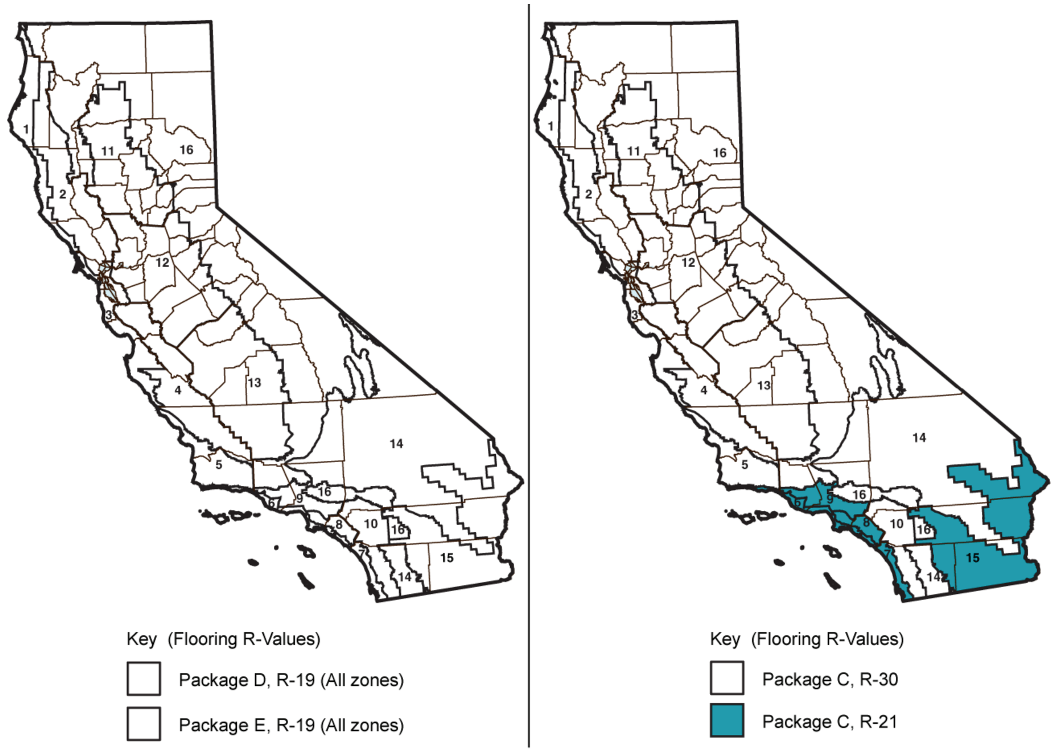
Raised floors must meet minimum insulation requirements (see Figure 3-16). Wood-framed floors must have at least R-13 insulation installed between framing members, or the construction must have a U-factor of 0.064 or less. The equivalent U-factor is based on R-13 insulation in a wood-framed floor and no crawlspace or buffer zone beneath the floor. The corresponding floor construction from Reference Joint Appendix JA4 is Table 4.4.2, cell entry A3. If comparing to a crawlspace assembly, the equivalent U-factor is 0.046, which includes the effect of the crawlspace. The corresponding floor construction from Reference Joint Appendix JA4 is Table 4.4.1, cell entry A3.

Other types of raised floors, except for concrete raised floors, must also meet these maximum U-factors. In all cases, some areas of the floor can have a U-factor that fails the requirements as long as other areas have a U-factor that exceeds the requirements and the area-weighted average U-factor is less than described above.

Raised slab floors with radiant heat must meet special insulation requirements that are described in Chapter 4 of this manual.

Table 4.4.1 from Reference Joint Appendix JA4 has U-factors for floors located over a crawlspace, and JA4 Table 4.4.2 has U-factors for floors located over ambient conditions. The difference is that R-6 insulation is added to approximate the buffering effect of the crawlspace. The additional R-6 is also included when modeling floors over crawlspaces with the performance method.

There is an exception to the mandatory measures for controlled ventilation crawlspaces. If all eligibility and installation criteria for a controlled ventilated crawlspace are met, raised floors above the controlled ventilation crawlspace need not meet the minimum insulation requirement. See the discussion below in the Compliance Options section.



Source: California Energy Commission

Figure 3-16 – Raised Floor Insulation Requirements by Climate Zone

Prescriptive Requirements

§151(f)1A

Package D and Package E prescriptive requirements call for R-19 insulation in raised floors in all climates. Package C requires R-21 in climate zones 6 through 9 and 15, and R-30 in the other climate zones.

The requirement may be satisfied by installing the specified amount of insulation in a wood-framed floor or by meeting an equivalent U-factor. Those U-factors are listed in Table 3-6 along with the corresponding constructions from Reference Joint Appendix JA4. Package D and Package E has separate requirements for concrete raised floors. This type of construction is typical for the floor that separates the first habitable floor of multifamily buildings from a parking garage. For this class of construction, R-4 insulation is required for climate zones 12 and 15, and R-8 is required for climate zones 1, 2, 11, 13, 14, and 16. No insulation is required in other climate zones. Package C indicates "NA" for concrete raised floor insulation, which means no insulation is required.

Table 3-6 – Raised Floor Constructions Used as Basis for Equivalent U-factor Compliance

Insulation R-value	Crawlspace?	Reference Joint Appendix JA4 Construction and Table Cell Entry	Equivalent U-factor
R-13	No	4.4.2 A3	0.064
R-13	Yes	4.4.1 A3	0.046
R-19	No	4.4.2 A4	0.048
R-19	Yes	4.4.1 A4	0.037
R-22	No	4.4.2 A5	0.044
R-22	Yes	4.4.1 A5	0.034
R-30	No	4.4.2 A7	0.034
R-30	Yes	4.4.1 A7	0.028

Construction Practice

Floor insulation should be installed in direct contact with the subfloor so that there is no air space between the insulation and the floor. Support is needed to prevent the insulation from falling, sagging, or deteriorating.

Options for support include netting stapled to the underside of floor joists, insulation hangers running perpendicular to the joists, or other suitable means. Insulation hangers should be spaced at 18 inch or less prior to rolling out the insulation. Insulation hangers are heavy wires up to 48 inch long with pointed ends, which provide positive wood penetration. Netting or mesh should be nailed or stapled to the underside of the joists. Floor insulation should not cover foundation vents.

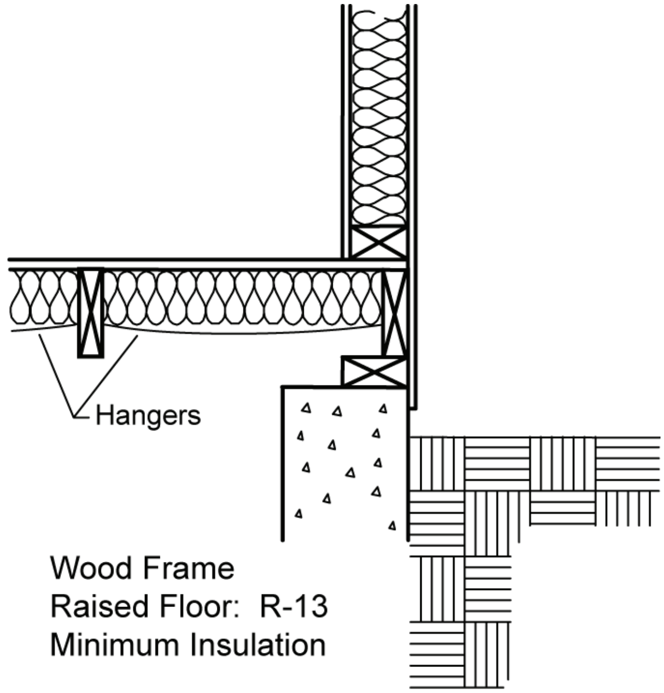


Figure 3-17 – Raised Floor Insulation

3.3.6 Slab Insulation

Mandatory Measures

§150(l)
§118(g)

The mandatory measures do not require slab insulation, but when the prescriptive requirements call for it, the mandatory measures require that the insulation material must be suitable for the application, with a water absorption rate no greater than 0.3 percent when tested in accordance with ASTM C272 Test Method A, 24-Hour-Immersion, and a vapor permeance no greater than 2.0 perm/inch when tested in accordance with ASTM E96. An example of an insulating material that meets these specifications is smooth-skin extruded polystyrene.

The insulation must also be protected from physical and UV degradation by either installing a water-resistant protection board, extending sheet metal flashing below grade, choosing an insulation product that has a hard durable surface on one side, or by other suitable means.

Slab edge insulation is mandatory with heated slabs, as required by §118(g) of the Standards. See Chapter 6 of this manual for details.

Prescriptive Requirements

§151(f)1

Prescriptive Package D and Package E require slab insulation only in climate zone 16. In this case, a minimum of R-7 must be installed. Package C requires R-7 slab insulation in all climates. The insulation must be installed to a minimum depth of 16 in. or to the bottom of the footing, whichever is less. The depth is measured from the top of the insulation, as near the top-of-slab as practical, to the bottom edge of the insulation (see Figure 3-18).

Perimeter insulation is not required along the slab edge between conditioned space and the concrete slab of an attached unconditioned enclosed space such as a garage, covered porch, or covered patio. Neither would it be practical or necessary to insulate concrete steps attached to the outside slab edge.

In situations where the slab is below grade and slab edge insulation is being applied to a basement or retaining wall, the top of the slab edge insulation should be placed as near to ground level as possible and extended down at least 16 inches. In situations where the slab is above grade and slab edge insulation is being applied, the top of the slab edge insulation should be placed at the top of the slab.

Example 3-14

Question

What are the slab edge insulation requirements for a hydronic-heating system with the hot water pipes in the slab?

Answer

The requirements for insulation of heated slabs can be found in §118(g) of the Standards and are described in Chapter 4 of this manual. The material and installation specifications are as follows:

- Insulation values as shown in Table 118-A of the Standards
- Protection from physical damage and ultra-violet light deterioration
- Water absorption rate no greater than 0.3% (ASTM-C-272)
- Water vapor permeance no greater than 2.0 perm/inch (ASTM-E-96)

Construction Practice

Slab-edge insulation should be protected from physical damage and ultraviolet light exposure because deterioration from moisture, pest infestation, ultraviolet light and other factors can significantly reduce the effectiveness of the insulation.

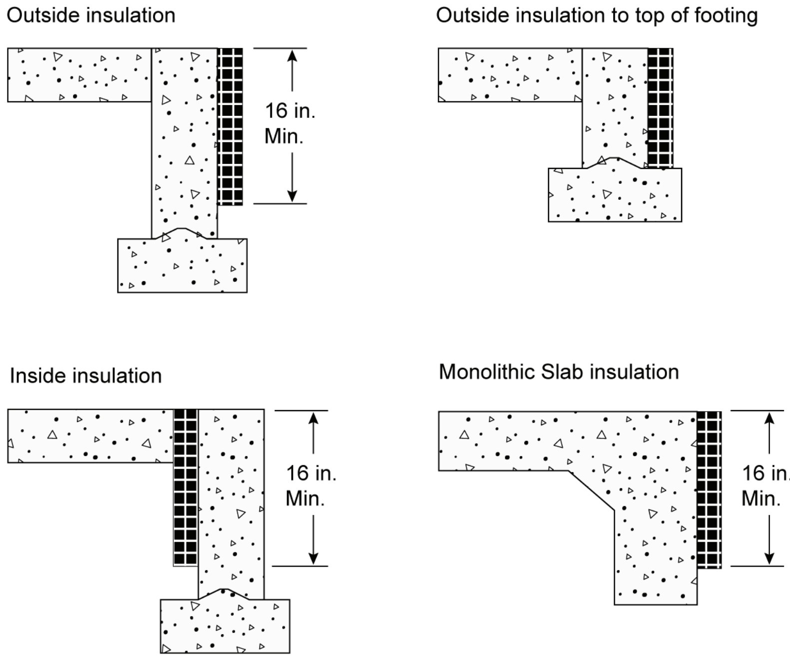


Figure 3-18 – Allowed Slab Edge Insulation Placement

When slab-edge insulation is required by the prescriptive or performance requirements, then minimum depth is 16 inch or to the top of the footing, whichever is less.

3.3.7 Compliance Options

Quality Insulation Installation

Energy Commission videos   *Reference Residential Appendix RA3.5*

Typical residential insulation installations have flaws that degrade thermal performance. Three problems are generally responsible for the degradation:

1. Insulation is not in contact with the air barrier creating live air spaces that short-cut the insulation.
2. The insulation has voids or gaps, resulting in portions of the construction assembly that are not insulated.
3. The insulation is compressed, creating a gap near the air barrier and/or reducing the thickness of the insulation.

Since these problems are so widespread, the Energy Commission assumes in its approved computer programs, prescriptive standards, and life-cycle cost analyses that insulation does not perform as effectively as standard U-factor calculations would indicate. Since the standard calculations are based on good quality installation, wall heat loss and heat gain are assumed to be 13.3 percent higher than a quality installation due to common installation and construction flaws. For ceiling/roof assemblies (including attics), the flaws are assumed to add 0.01 to the heating U-factor and 0.003 to the cooling U-factor relative to assemblies with verified quality insulation installations.[4]

The calculated U-factors that are presented in Reference Joint Appendix JA4 do not include these adjustments; rather they are automatically added by Energy Commission approved software.

Although Reference Residential Appendix RA3.5 is quite thorough and needs to be understood in its entirety, two matters warrant additional elaboration in this manual.

1. It is important to maintain contact between the wall and ceiling insulation and the interior sheetrock that forms the air barrier to prevent convection from reducing the effectiveness of the insulation. This is an issue particularly for knee walls, skylight wells, and underfloor insulation where there is traditionally no drywall or other backing material to help maintain contact between the interior surface material and the insulation. It is also a common problem when batt ceiling insulation is installed before the ceiling drywall. And it is a problem when hard covers or draft stops are not installed over drop ceilings, lighting soffits, interior and exterior wall cavities, and other interstitial spaces to form an air barrier with which the insulation will maintain contact.
2. When different areas of the ceiling are intended to have different insulation levels, compliance documentation must separately report each area and its insulation characteristics in the compliance program. For example, if an attic furnace platform is installed with less insulation under the platform than in the remainder of the attic, then the compliance forms must have separate input for the insulation characteristics for the area under the platform and remainder of the ceiling insulation. Within each of the areas that are separately listed on compliance documentation, the insulation thickness and density must be uniform.

Examples of poorly installed insulation are shown in Figure 3-19.

With the performance method, designers and contractors can get credit for correctly installing insulation to eliminate or reduce the problems described above. Reference Residential Appendix RA3.5 contains a procedure for verifying the quality of insulation installation in low-rise residential buildings. Credit for installation of medium density closed cell spray polyurethane foam in residential building is given when the required installation procedures described in Reference Joint Appendix JA7 are followed. Through the performance approach, a compliance credit is offered when this procedure is followed by the insulation installer and verified by a qualified HERS rater.

The procedure and credit apply to wood-framed construction with wall stud cavities, ceilings, and roof assemblies insulated with mineral fiber or cellulose insulation in low-rise residential buildings. The procedure does not allow any

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[4] See the 2008 Reference Residential Appendix RA3.5

credits for floor assemblies. The ceiling/roof constructions are presented in Reference Joint Appendix JA4, Tables 4.2.1 and 4.2.2, and the wall assemblies presented in Table 4.3.1.

The credit does not apply to other construction assemblies listed in Reference Joint Appendix JA4, including metal-framed walls and ceiling/roof assemblies and SIPS. For non-wood framed assemblies, approved computer programs do not modify the thermal performance of the building envelope component as described above.

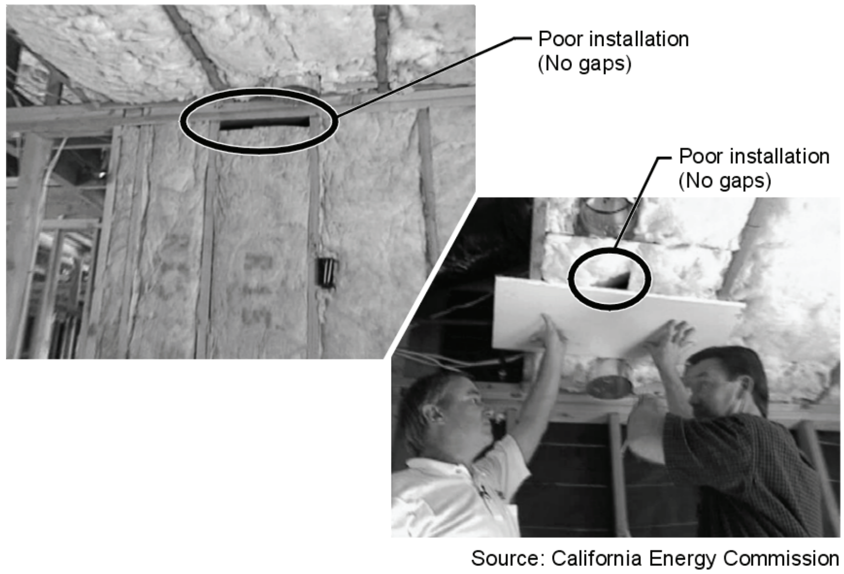

Figure 3-19 – Examples of Poor Quality Insulation Installation

Sprayed Wall Insulation

See Energy Commission videos.

Sprayed wall insulation can be an effective way to deal with the irregularities of wall and ceiling cavities, especially the spaces around pipes, electric cables, junction boxes, and other equipment that is embedded in cavities. There are several types of sprayed insulation, including cellulose (see Figure 3-20), fiberglass and spray polyurethane foam (SPF). Cellulose is basically paper that has been treated for flame- and insect-resistance. The product is similar to the loose fill cellulose that is commonly used in attic insulation retrofits, but for walls it is mixed with a water- and starch-based binder. The binder causes the insulation to stick to the surfaces of the wall cavity. Excess insulation that extends past the wall cavity is scraped off with a special tool and recycled into the hopper with the fresh insulation.

Loose fill fiberglass insulation

Loose fill fiberglass insulation is made up of small glass fibers. The product is similar to loose fill fiberglass that is commonly used in attics, but for walls it can be installed behind a netting fabric or mixed with water based adhesive. The adhesive causes the insulation to adhere to surfaces of the wall cavity. Excess insulation that extends past the wall cavity is scraped off and recycled. Loose fill fiberglass insulation shall use batt insulation assembly U–factors listed in

Reference Joint Appendix JA4. See Reference Residential Appendix RA3.5.5.2 for more Quality Insulation Installation (QII) requirements.

Spray Polyurethane Foam (SPF)

Spray polyurethane foam insulation is a foamed plastic formed by the combination of chemicals and a blowing agent applied using a spray gun. SPF insulation is spray applied to fully adhere to the joist and other framing faces to form a complete air seal within the construction cavities.

There are two types of SPF insulation; medium density, or closed cell, and low density, or open cell insulation. They have different insulating properties, and compliance requirements as described below.

Medium density, closed cell SPF has been assigned an R-value of 5.8 per inch for compliance purposes and a nominal density of 2.0 ±0.5 pounds per cubic foot.

Medium density SPF must be applied following the procedures detailed in Reference Joint Appendix JA7. The insulation shall be installed at the average thickness required to achieve the specified R-value of the assembly documented on the CF-1R. The installation thickness applied to meet these R-values levels shall be documented on the Installation Certificate (CF-6R). The nominal thickness of the SPF insulation shall be such that (1) the average thickness shall be equal to or greater than that required to meet the design R-value of the assembly, and (2) the minimum tested thickness shall be no more than ½ inch less than the required thickness for the R-value.

Medium density is not required to fill the cavity. The insulation thickness shall be verified by using probes capable of penetrating the full thickness of the insulation with measurements marked by eighth inch increments Measurements shall be accurate to within ±1/8 inch. The probes shall be used by HERS Raters to verify proper thickness of insulation has been applied.

A compliance credit for quality insulation installation is available when the required procedures detailed in Reference Joint Appendix JA7 are followed and verified by a qualified HERS rater. The credit only applies to low rise-residential buildings, the procedure and credit applies to wood or metal framed wall, ceiling, and/or roof assemblies insulated with SPF insulation. Review Section 3.3.2 of this document or see Reference Residential Appendix RA3.5 for more discussion of Quality Insulation Installation (QII).

Low density SPF open cell insulation has an R-value of 3.6 per inch and a density of 0.5 lbs/ft^2. Low density, open cell SPF insulation is sprayed into the cavity then expands to fill the cavity. Excess insulation is removed with a special tool. Low density SPF insulation shall use spray insulation assembly U-factors listed in Reference Joint Appendix JA4. No quality insulation installation compliance credit is allowed for low density SPF insulation.

U-factors for sprayed insulation are provided in *Reference Joint Appendix JA4* (Tables 4.2.2, 4.2.5, 4.3.1, 4.3.3, and 4.3.4) for both framed walls (wood or metal) as well as for rafter roofs (wood or metal). The thermal performance of cellulose and foamed plastic is similar, and one set of data is provided for both. The data in Reference Joint Appendix JA4 assumes that the cavity of rafter roof constructions can be completely filled (no ventilation). Check with the building official in your area to verify that this method of insulation is acceptable.

Source: California Energy Commission

Figure 3-20 – Cellulose Insulated Wall

Metal Framing

A change from wood framing to metal framing can significantly affect compliance. Metal and wood framing are not interchangeable.

Metal-framed wall construction generally requires a continuous layer of rigid insulation to meet the mandatory minimum wall insulation levels and/or the prescriptive requirements since metal is more conductive than wood. In Reference Joint Appendix JA4, Tables 4.2.4 and 4.2.5 have U-factors for metal-framed ceiling/roof constructions. Table 4.3.4 has U-factors for metal-framed walls. Tables 4.4.4 and 4.4.5 have U-factors for metal-framed floors.

To comply prescriptively, a non-wood framed assembly, including a metal framed assembly, must have an assembly U-factor that is equal or less than the U-factor of the wood framed assembly for that climate zone; compliance credit is available through the performance path for metal framed assemblies that exceed the prescriptive requirements of the equivalent wood framed assemblies.

Log Homes Compliance Option

Log homes are an alternative construction type used in some parts of the state. Log home companies promote the aesthetic qualities of solid wood construction and can "package" the logs and deliver them directly to a building site. Some companies provide log wall, roof, and floor systems with special insulating "channels" or other techniques to minimize the effect of air infiltration between log members and to increase the thermal benefit of the logs.

Log walls do not have framing members like conventional wood stud walls. Therefore, the mandatory requirement for a minimum of R-13 wall insulation does not apply.

Otherwise, in prescriptive compliance log walls must meet the same thermal requirements as other construction types. For performance compliance, consult the compliance software vendor's documentation for any unique modeling requirements for mass walls using values from Reference Appendices. In prescriptive compliance, the walls will qualify as either light mass or heavy mass walls depending on the thickness – remember a heat capacity (HC) of 8.0 Btu/°F-ft² is equivalent to a heavy mass wall (40 lb/ft³). The prescriptive requirements for heavy mass walls are less stringent than the criteria for wood-framed walls. Reduced insulation is allowed because the effects of the thermal mass (interior and exterior) can compensate for less insulation.

The thermal performance of log walls is shown in Reference Joint Appendix JA4, Table 4.3.11. The U-factor ranges from 0.133 for a 6-inch wall to 0.053 for a 16-inch wall. The U-factor of an 8-inch wall is 0.102, which complies with the R-13 prescriptive requirements. U-factors for other log wall constructions (not shown in Reference Joint Appendix JA4) would have to be approved by the Energy Commission through the exceptional methods process.

Log walls have a heat capacity that is in excess of conventional construction. Reference Joint Appendix JA4 [Table 4.3.11 Thermal Properties of Log Home Walls] shows that a 6-inch wall has an HC of 4.04 which increases to 10.77 for a 16-inch wall. The thermal mass effects of log home construction can be accounted for within the performance approach.

Air infiltration between log walls can be considerably different among manufacturers depending upon the construction technique used. For purposes of compliance, infiltration is always assumed to be equivalent to a wood-frame building. However, the builder should consider using a blower door test to find and seal leaks through the exterior walls.

Straw Bale Construction

In 1995, the California Legislature passed AB1314, a bill that authorizes all California jurisdictions to adopt building codes for houses with walls constructed of straw bales. The bill provided guidelines for moisture content, bale density, seismic bracing, weather protection, and other structural requirements.

Several years ago, the Energy Commission, in conjunction with research and testing facilities, determined the thermal properties needed for straw bale walls to comply with the Standards. The thermal mass benefit of straw bale construction can be credited only through the use of the computer performance compliance approach by modeling straw bale construction using the heat capacity characteristics of the straw bales given below.

Straw bales that are 23 inch by 16 inch are assumed to have a thermal resistance of R-30, whether stacked so the walls are 23 inch wide or 16 inch wide. Performance data on other sizes of bales is not available. The minimum density of load bearing walls is 7.0 lb/ft^3, and this value or the actual density may be used for modeling straw bale walls in the performance approach. Specific heat is set to 0.32 Btu/lb-°F. Volumetric heat capacity (used in some computer programs) is calculated as density times specific heat. At a density of 7 lb/ft³, for example, the volumetric heat capacity is 2.24 Btu/ft³-°F.

The minimum dimension of the straw bales when placed in the walls must be 22 inch by 16 inch there are no restrictions on how the bales are stacked. Due to the higher resistance to heat flow across the grain of the straw, a bale laid on edge with a nominal 16-inch horizontal thickness has the same R-Value (R-30) as a bale laid flat.

For performance compliance, consult the compliance program's documentation for any unique modeling requirements for mass walls using values from Reference Appendices RA5.

Structural Insulated Panels (SIPS)

Structural Insulated Panels (SIPS) are an advanced method of constructing walls, roofs and floors. SIPS consist of rigid insulation (usually expanded polystyrene) sandwiched between two sheets of OSB or plywood. Little or no structural framing penetrates the insulation layer. Panels are typically manufactured at a factory and shipped to the job site in assemblies that can be as large as 8 ft by 20 ft.

In the field, the SIPS panels are joined in one of two ways (see Figure 3-21) and the choice affects thermal performance. The first way is to use wood spacers at the joints. These spacers allow thermal bridging but they are spaced no closer than about 48 inch The second way of joining SIPS panels is to use an OSB spline. With this technique, the insulation is notched or routed just in back of the OSB panels on each side. An OSB strip is then inserted into the pocket on each side of the panel and the assembly is fastened together with wood screws.

Reference Joint Appendix JA4, Table 4.3.2 has U-factors for SIPS wall assemblies. Table 4.2.3 has U-factors for roof/ceiling assemblies and Table 4.4.3 has U-factors for SIPS floor constructions. U-factors used for compliance must be taken from these tables. If manufacturers develop SIPS assemblies that are not adequately represented by choices in these tables, they may obtain approval of these assemblies through the Energy Commission's exceptional methods process.

The credits for Quality Insulation Installation do not apply for SIPS construction.

Source: California Energy Commission

Figure 3-21 – Methods of Joining SIPS Panels

Controlled Ventilation Crawlspace

CVC Eligibility Criteria in 2008Reference Residential Appendix RA4.5.1

The Energy Commission has approved an exceptional method for buildings with raised floors that use foundation wall insulation and have automatically controlled crawl-space vents. The method is available as an option using the performance method. Refer to Figure 3-22.

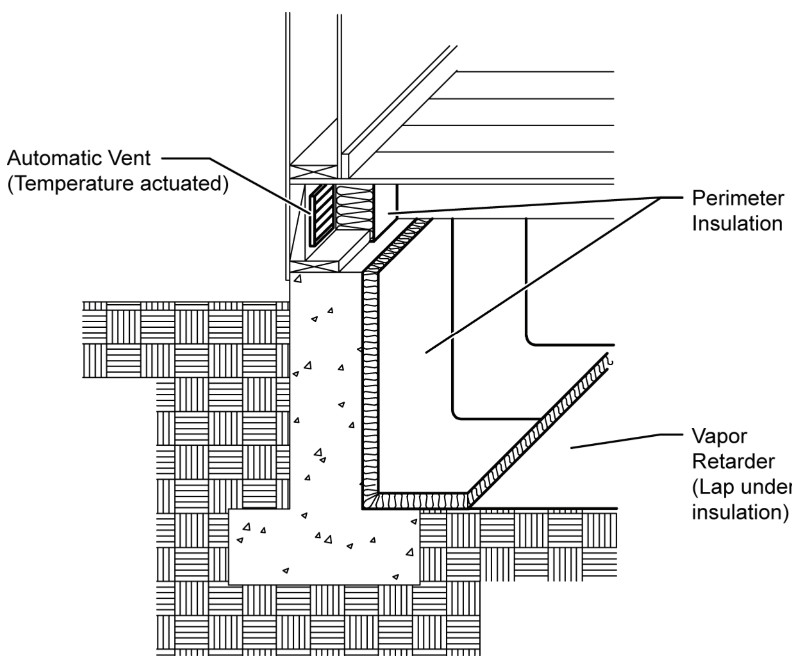

Figure 3-22 – Controlled Ventilation Crawl Space

The following eligibility criteria (from the 2008 Reference Residential Appendix RA4.5.1) are required in order to take credit for a controlled ventilation crawlspace:

1. **Drainage.** Proper enforcement of site engineering and drainage, and emphasis on the importance of proper landscaping techniques in maintaining adequate site drainage, is critical.
2. **Ground Water and Soils.** Local ground water tables at maximum winter recharge elevation should be below the lowest excavated site foundation elevations. Sites that are well drained and that do not have surface water problems are generally good candidates for this stem-wall insulation strategy. However, the eligibility of this alternative insulating technique is entirely at the building officials' discretion. Where disagreements exist, it is incumbent upon the applicant to provide sufficient proof that site drainage strategies (e.g., perimeter drainage techniques) will prevent potential problems.
3. **Ventilation.** All crawl space vents must have automatic vent dampers to receive this credit. Automatic vent dampers must be shown on the building plans and installed. The dampers should be temperature actuated to be fully closed at approximately 40°F and fully open at approximately 70°F. Cross ventilation consisting of the required vent area reasonably distributed between opposing foundation walls is required.
4. **Foam Plastic Insulating Materials.** Foam plastic insulating materials must be shown on the plans and installed when complying with the following requirements:
   - Fire Safety—CBC Section 1712(b)2. Products shall be protected as specified. Certain products have been approved for exposed use in under floor areas by testing and/or listing.
   - Direct Earth Contact—Foam plastic insulation used for crawl-space insulation having direct earth contact shall be a closed cell water resistant material and meet the slab-edge insulation requirements for water absorption and water vapor transmission rate specified in the mandatory measures.

- **Use of a Vapor Barrier (Ground Cover).** A ground cover of 6 mil (0.006 inch thick) polyethylene, or approved equal, must be laid entirely over the ground area within crawl spaces:

  1. The vapor barrier must be overlapped 6 inch minimum at joints and must extend over the top of pier footings.
  2. The vapor barrier should be rated as 1.0 perm or less.
  3. The edges of the vapor barrier should be turned up a minimum of 4 inches at the stem wall.

4. Penetrations in the vapor barrier should be no larger than necessary to fit piers, beam supports, plumbing and other penetrations.
5. The vapor barrier must be shown on the plans and installed.
6. If the crawl space ground slopes, the vapor barrier should be spiked in place with 5 inch gutter nails.

3.4 Thermal Mass

Thermal mass consists of exposed tile floors over concrete, mass walls such as stone or brick, and other heavy elements within the building envelope that serve to stabilize indoor temperatures. Thermal mass acts for temperature much like a flywheel – it tends to keep things warmer when it is cold outside and keep things cooler when it is hot outside. In California's central valley and desert climates, the summer temperature range between night and day can be 30°F or more and thermal mass can be an effective strategy to reduce daytime cooling loads.

When thermal mass exists in exterior walls, it works to stabilize temperatures in two ways. First, there is a time delay between when the outside temperature of the wall reaches its peak and when the inside of the wall reaches its peak. For an 8-inch to 12-inch concrete wall, this time delay is on the order of 6 to 10 hours. Second, there is a dampening effect whereby the temperature range on the inside of the house is less than the temperature range on the outside of the house. These effects are illustrated in Figure 3-23.

Interior thermal mass is especially important in passive solar buildings. Passive solar buildings have large areas of south-facing fenestration. The large window area means that solar gains are quite high on winter days when the south sun is low in the sky (passive solar buildings should have south overhangs to block the sun in the summer). Large window areas also contribute to increased heat loss in the evening and at night. Without thermal mass, the south glass would create uncomfortably warm temperatures in the day and uncomfortably cold temperatures at night. Thermal mass in passive solar buildings works best if it is positioned so that the sun strikes it during the day. It can then better absorb the solar radiation for release later in the day when the space begins to cool.

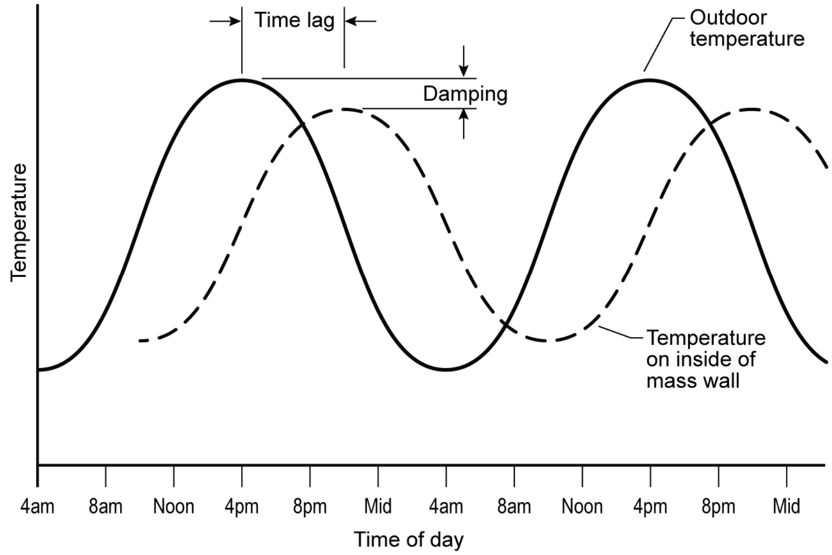

Figure 3-23 – Thermal Mass Performance

3.4.1 Mandatory Measures

There are no mandatory measures for thermal mass.

3.4.2 Prescriptive Requirements

§151(f)5

Reference Residential Appendix RA5

Table 151-A

Package D and Package E have no requirements for thermal mass, however Package C requires mass. The prescriptive requirements call for a minimum interior mass capacity (IMC). The IMC requirement for slab-on-grade buildings is 2.36 times the ground floor area. For raised floor buildings, the mass requirement is 0.18 times the ground floor area.

The Package C interior mass requirement for slab-floor buildings is equivalent to having 20 percent of the *ground floor slab area* exposed to the conditioned space.[5] A Package C slab-floor building may meet its thermal mass requirement by either calculating the IMC of all of the mass elements in the building, or by exposing 20 percent of a 3.5 inch concrete slab. Exposing the slab means covering it with tile or other materials (other than carpet) that have minimum insulating ability. See Compliance Options below for acceptable methods of "exposing" the thermal mass elements. The interior mass requirement for Package C raised-floor buildings is based on having mass equivalent in

[5] This assumes a standard weight (140lb/ft³) concrete slab at least 3.5 inch thick.

performance to 5 percent of the ground floor area consisting of exposed 2-inch thick concrete.[6]

IMC is a measure of the total thermal mass in a low-rise residential building. The procedure for calculating IMC is documented in Reference Residential Appendix RA5. This procedure is used to show compliance with the Package C prescriptive requirement (using Form WS-1R) as well as for credit under the performance approach.

Each material that contributes to the IMC has a unit interior mass capacity (UIMC) associated with it. For instance, the UIMC associated with a 6-inch exposed concrete slab is 5.1 Btu/°F-ft². If the slab is covered with a carpet, the UIMC is only 1.9 Btu/°F-ft². The UIMC of a solid-grouted 8inch concrete masonry interior wall exposed on both sides is 9.6 Btu/°F-ft² from Table RA5-2. Tables RA5-1, RA5-2, and RA5-3 of the Reference Residential Appendix RA5 have UIMC data for common interior mass materials.

The procedure outlined in Reference Residential Appendix RA5 involves determining the surface area of each qualifying mass element, multiplying the area by the UIMC for that element, and summing the IMC values for all the mass elements. This procedure is shown in Equation RA5-1. This method allows for multiple mass types common in low-rise residential construction.

Example 3-15

Question

A Package C building has 1,000 ft² of first floor area which is slab-on-grade and another 800 ft² of second floor area. What is the requirement for IMC?

Answer

The total IMC requirement is the ground floor area of 1,000 ft² times the requirement of 2.36 Btu/°F- ft². The requirement is therefore, 2,360 Btu/°F. The second floor is not considered in determining the requirement.

3.4.3 Compliance Options

When the performance method is used, credit is offered for increasing thermal mass in buildings. However, credit for thermal mass in the proposed design may be considered only when the proposed design qualifies as a high mass building. A high mass building is one with thermal mass equivalent to having 30 percent of the conditioned slab floor exposed and 15 percent of the conditioned non-slab floor exposed 2 inch-(50 mm) thick concrete.

IMC is used to determine if a building qualifies as a high mass building, following the procedure in Reference Residential Appendix RA5. This procedure is automated in Energy Commission approved computer programs so there is no need to perform the calculations by hand.

[6] The concrete is assumed to have a volumetric heat capacity of 28, a conductivity of 0.98, a surface conductance of 1.3 and no thermal resistance on the surface. The heat capacity and conductivity performance equivalent referred to is that of standard 140 lb/ft³ concrete.

3.5 Infiltration and Air Leakage

3.5.1 Overview

Infiltration is the *unintentional* replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. It is a major component of heating and cooling loads.

Reduction in building envelope air leakage can result in significant energy savings, especially in climates with more severe winter and summer conditions. It also can result in improved building comfort, reduced moisture intrusion, and fewer air pollutants due to leakage from garages or attics. Credit is offered through compliance methods for options that reduce building envelope air leakage.

Ventilation is the *intentional* replacement of conditioned air with unconditioned air through open windows or mechanical ventilation. Ventilation in residential buildings can be achieved by opening windows either to provide natural ventilation for cooling purposes or to reduce stuffiness or odors. Energy Commission sponsored research in California homes has shown that a significant number of home occupants do not regularly open their windows for ventilation. Starting with the 2008 update it is mandatory to meet the requirements of ASHRAE Standard 62.2 which include mechanical ventilation and minimum openable window area requirements. See Section 4.6 for mechanical ventilation requirements.

3.5.2 Mandatory Measures

Ventilation Opening Area

ASHRAE Standard 62.2 requires ventilation openings in habitable spaces, toilets and utility rooms. Ventilation openings usually will mean operable windows, although a dedicated non-window opening for ventilation is acceptable. Spaces that meet the local exhaust requirements are exempted from this requirement so a complying exhaust system can be substituted for a ventilation opening (see Section 4.6.6).

Habitable Spaces

Habitable spaces are required to have ventilation openings with openable area equal to at least 4 percent of the space floor area (but not less than 5 ft^2). Rooms people occupy are considered habitable space. Dining rooms, living rooms, family rooms, bedrooms and kitchens are considered habitable space. Closets, crawl spaces, garages and utility rooms are generally not. If the washer and dryer are located in an open basement that is also the family room, it would be considered habitable space.

The openings do not have to be provided by windows. They can also be provided by operable, insulated, weather-stripped panels.

Ventilation openings, which include windows, skylights, through-the-wall inlets, window air inlets, or similar devices, shall be readily accessible to the occupant.

This means that the occupant must be able to operate the opening without having to climb on anything. An operable skylight must have some means of being operated while standing on the floor; a push rod, a long crank handle, or an electric motor.

If a ventilation opening is covered with louvers or otherwise obstructed, the openable area is the unobstructed free area through the opening.

Example 3-16 – Ventilation Openings

Question

I am building a house with a 14 ft. by 12 ft. bedroom. What size window do I need to install?

Answer

It depends on the type of window. The standard requires that the openable area of the window, not the window unit, be 4% of the floor area, or 14ft x 12ft x 0.04 = 6.7 ft^2. The fully opened area of the window or windows must be greater than 6.7 ft^2. The requirement for this example can be met using two double hung windows each with a fully opened area of 3.35 ft^2. Any combination of windows whose opened areas add up to at least 6.7 ft^2 will meet the requirement.

There are different minimum requirements for existing (“egress”) in habitable rooms. These are Health and Safety Code requirements and typically require enough openable window area to exit the building through the window. Consult other code requirements because your energy compliance will need to include your total fenestration area.

Example 3-17 – Ventilation Opening Louvers

Question

There are fixed wooden louvers over a window in a bedroom. The louvers have slats that are 1/8 in thick, and they are spaced 1 inch apart. What is the reduction in openable area?

Answer

Assuming that the 1 inch spacing was measured perpendicular to the slats (the correct way), then the reduction is the slat thickness divided by the spacing, or 1/8 inch. So the credited opening area is the original opening area x (1inch – 1/8 inch)/1inch = 7/8 inch of the original opening area.

Fenestration Air Leakage

Mandatory measures for air leakage for fenestration products are covered in Section 3.2.2.

Joints and Other Openings

§117

Air leakage through cracks around windows, doors, walls, roofs and floors can result in higher energy use for home heating and cooling than necessary. The following openings in the building envelope must be caulked, gasketed, weatherstripped or otherwise sealed (see Figure 3-24):

1. Exterior joints around window and door frames, including doors between the house and garage, between interior HVAC closets and conditioned space, between attic access and conditioned

space, and between wall sole plates, floors, exterior panels and all siding materials;

2. Openings for plumbing, electricity, and gas lines in exterior walls, ceilings and floors;
3. Openings in the attic floor (such as where ceiling panels meet interior and exterior walls and masonry fireplaces);
4. Openings around exhaust ducts such as those for clothes dryers; and
5. All other such openings in the building envelope

Note also that range hoods must have dampers.

Alternative approved techniques may be used to meet the mandatory caulking requirements for exterior walls. These include, but are not limited to:

1. Continuous stucco,
2. Caulking and taping all joints between wall components (e.g., between slats in wood slat walls),
3. Building wraps, and
4. Rigid wall insulation installed continuously on the exterior of the building.

Weatherstripping is required for all field-fabricated operable windows and doors (other windows and doors must meet infiltration requirements and be laboratory tested). This includes doors between the garage and the house, between interior HVAC closets and conditioned space, and between the attic access and conditioned space.

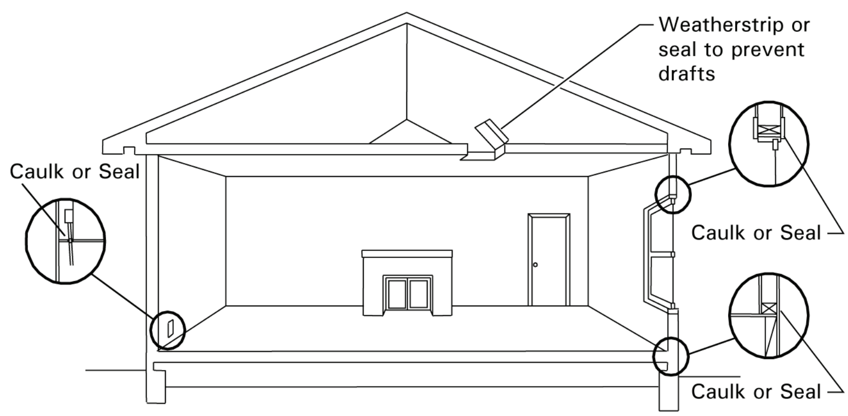

Figure 3-24 – Caulking and Weatherstripping

Fireplaces, Decorative Gas Appliances and Gas Logs

§150(e)

The Standards have mandatory measurements to limit infiltration associated with fireplaces, decorative gas appliances, and gas logs. Fireplace efficiency can be greatly improved through proper air control, and reduced infiltration is also a benefit when the fireplace is not operating (the majority of the time for most houses).

Installation of factory-built or masonry fireplaces (see Figure 3-25) must include the following:

1. Closable metal or glass doors covering the entire opening of the firebox;
2. Doors covering the entire opening of the firebox that can be closed when the fire is burning. A combustion air intake that is at least 6 inch^2 to draw air from outdoors equipped with a readily accessible, operable and tight-fitting damper or combustion air control device;
3. A combustion air intake that is at least 6 inch^2 to draw air from outdoors equipped with a readily accessible, operable and tight-fitting damper or combustion air control device (*Exception*: An outside combustion air intake is not required if the fireplace is installed over concrete slab flooring and the fireplace is not located on an exterior wall); and
4. A flue damper with a readily accessible control. (*Exception:* When a gas log, log lighter or decorative gas appliance is installed in a fireplace, the flue damper shall be blocked open if required by the manufacturer's installation instructions or the California Mechanical Code.)

Continuous burning pilot lights are prohibited for fireplaces as well as for decorative gas appliances and gas logs. In addition, indoor air may not be used for cooling a firebox jacket when that indoor air is vented to the outside of the building.

When a gas log, log lighter or decorative gas appliance is installed in a fireplace, the flue damper must be blocked open if required by the manufacturer's installation instructions or the California Mechanical Code.

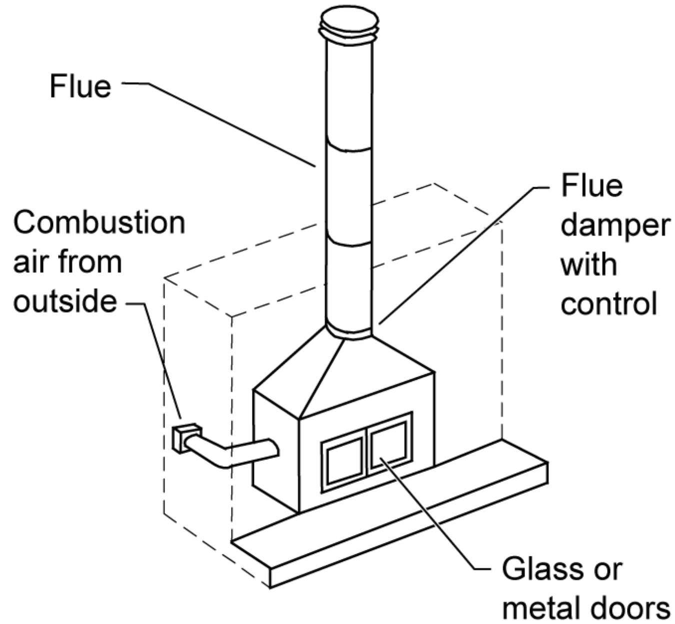

Figure 3-25 – Fireplace Installation

Example 3-18

Question

Are closable glass or metal doors required for decorative gas appliances?

Answer

No. The only requirements that apply to decorative gas appliances are the prohibition on continuously burning pilot lights and the prohibition on using indoor air to cool the firebox if the air is then vented to outdoors. If there is a question about whether a device is a fireplace, which requires glass doors, the distinction is that a fireplace has a hearth, chamber or other place in which a solid fuel fire or a decorative gas log set may be burned, while a decorative gas appliance is for visual effect only and merely simulates a fire in a fireplace.

Example 3-19

Question

If I want to have a gas log or some other device in the fireplace of my home, can I block open the damper? Can it have a standing pilot light?

Answer

§150(e)1 (which contains the requirements for fireplaces, decorative gas appliances, and gas logs), allows the flue damper to be blocked open if required by either the manufacturer's installation instructions or the California Mechanical Code. Continuously burning pilot lights in these appliances are prohibited by §150(e)2.

Example 3-20

Question

§150(e)2 states that no fireplace, decorative gas appliance or gas log can be installed if it has a continuously burning pilot light. The California Mechanical Code requires all gas appliances installed in California to have a manually operated shut-off valve, accessible to the inhabited space. Does this shut-off valve meet the intent of this section?

Answer

Not if the pilot light must be manually extinguished when the appliance is off. A unit that meets the intent of this section will have a pilot light that cannot stay on when the unit is off.

Example 3-21

Question

A building plan specifies a freestanding gas heater that is decorative; however, the equipment is vented and is rated as a room heater. Is it acceptable that this appliance have a pilot light?

Answer

Yes. Since this equipment is rated as a room heater, it can have a continuous burning pilot light.

Example 3-22

Question

Do decorative gas appliances need glass or metal doors?

Answer

Decorative gas appliances do not need doors. The door requirement applies to masonry or factory-built fireplaces only. If a decorative gas appliance is installed inside a fireplace, the fireplace needs doors. Consult with the manufacturer of the decorative gas appliance regarding combustion air requirements.

3.5.3 Compliance Options

There are several ways to take credit for infiltration reduction measures that go beyond the mandatory measures. Credit requires use of the performance compliance method and is implemented through lower air leakage assumptions. One option is blower-door testing to get an estimate of actual leakage area. Alternatively, credit is available for testing and sealing ducts and for installation of a “house wrap” (air retarding wrap).

Approved computer programs use a default specific leakage area (SLA) of 4.3 for proposed designs that do not take compliance credit for building envelope sealing. Algorithms approved by the Energy Commission keep track of the combination of infiltration, ventilation through opening windows, and continuous mechanical ventilation. Approved computer programs can be used to determine optimal building envelope leakage levels that can be specified for compliance purposes.

Reduced Duct Leakage

If compliance credit is not taken for reduced building envelope air leakage through diagnostic testing (as described in detail below), a special “default” compliance credit can be taken for building envelope leakage reduction. To qualify for this credit all requirements for reduced duct leakage (see Section 4.4.3 of this manual), including diagnostic testing, must be met. A “default” reduction in SLA of 0.50 is allowed for this credit. This adjustment reduces the standard SLA from 4.3 to 3.8.

Air-Retarding Wrap Credit

§150(f)

If compliance credit is not taken for reduced building envelope air leakage through diagnostic testing, a special “default” compliance credit can be taken for building envelope leakage reduction resulting from installation of an air-retarding wrap.

Compliance credit is provided for a “default” reduction in SLA of 0.50 for an SLA of 3.8. This credit may be combined with the credit for reduced duct leakage, reducing the SLA by a total of 1.0, from 4.3 to 3.3.

To qualify for the “default” compliance credit, an air-retarding wrap must be tested and labeled by the manufacturer to comply with ASTM E1677-95, *Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building* Walls, and have a minimum perm rating of 10. Insulating sheathing and building paper do not qualify as air-retarding wraps.

The air-retarding wrap must be installed per the manufacturer’s specifications. In particular, it must meet the following installation requirements:

1. The air-retarding wrap must be applied continuously,
2. All tears or breaks must be repaired with manufacturer approved tape,
3. All horizontal seams must be lapped in a shingle-like manner and taped,
4. All vertical seams must be lapped,
5. All windows and penetrations must be taped or caulked, and
6. The air-retarding wrap must be taped or otherwise sealed at the slab junction.

When compliance credit is taken for an air-retarding wrap, the computer program will automatically include it and the above specifications in the *Special Features and Modeling* Assumptions section of the CF-1R to facilitate inspection by the local enforcement agency. Compliance credit for an air-retarding wrap does not require HERS rater verification.

Source: California Energy Commission

Figure 3-26 – Air-Retarding Wrap

Blower Door Testing

Additional credit is available through the performance approach when the house is specially sealed. This credit requires that the reduced building envelope leakage be verified through diagnostic testing. The testing process involves closing all the windows and doors, pressurizing the house with a special fan, usually positioned in a doorway (see Figure 3-27), and measuring the leakage. While the house is pressurized, it is usually possible to locate leaks and to correct them so that the house leakage reaches a desirable level.

Source: California Energy Commission

Figure 3-27 – Blower Door Testing

Changing the input for SLA in the computer calculation methods will show how much compliance credit is achievable with reduced infiltration. Compliance programs will report the corresponding target value for blower door test results, which is usually expressed in terms of $cfm50_H$ (cfm of air leakage when the home is pressurized to 50 Pascals). The default SLA value for a home that has not been tested is 4.3 ft² of leakage area per 10,000 ft² of floor area.

The procedure for performing the test and making the measurements is one that has been worked out through a consensus process involving experts in the field. The procedure is documented as ASTM E-779-03, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*.

The target $cfm50_H$ value required for the blower door testing will be listed in the HERS Required Verification section on the CF-1R. The installer must perform tests to demonstrate that building envelope leakage has been reduced to the target $cfm50_H$ level or lower and document the blower door test results on the CF-6R. An approved HERS rater must also do blower door testing to verify that the target $cfm50_H$ has been achieved. The HERS rater testing is documented on the CF-4R.

Mechanical Outside Air Ventilation

"Unusually tight" building envelope construction requires mechanical ventilation that will not cause dangerous pressure imbalances. The Energy Commission considers dwellings with target or measured SLA values of 1.5 or less to be "unusually tight construction" per the California Mechanical Code, and requires that such dwellings must meet specific ventilation criteria. When the dwelling target or measured SLA is below 1.5, combustion and solid-fuel burning appliances must be provided with adequate combustion and ventilation air from outside the structure in accordance with the requirements of ASHRAE Standard 62.2 Section 6.4.

Refer to Chapter 4 Section 6 of this manual for information about the ASHRAE Standard 62.2 requirements. Section 4.6.5 provides information about the requirements for Combustion and Solid-fuel Burning Appliances.

3.6 Vapor Barriers and Moisture Protection

A vapor barrier or retarder is a special covering over framing and insulation that protects the wall assembly components from possible damage due to moisture condensation. During cold weather, the inside of the house is warm and moist (from breathing, showers, etc.) and the outside is cold and dry. Moisture moves from more to less and from warm to cold. When the moisture (in vapor form) reaches a point in the wall or roof assembly that has a temperature below the dew point, it will condense into liquid water. Water build up can cause structural damage, create mold that may contribute to indoor air quality problems and can cause the insulation to lose its effectiveness.

3.6.1 Mandatory Measures

§150(g)

Reference Residential Appendix RA4.5.2

In climate zones 14 and 16, a continuous vapor barrier, lapped or joint sealed, must be installed on the conditioned space side of all insulation in all exterior walls, on the floors of unvented attics, and on floors over unvented crawl spaces to protect against moisture condensation.

If a building has a controlled ventilation crawl space (see Section 3.3.7), a vapor barrier must be placed over the earth floor of the crawl space to reduce moisture entry and protect insulation from condensation in accordance with Reference Residential Appendix RA4.5.2.

The Standards define a vapor barrier as material with a permeance of one perm or less. A perm is a measure of resistance to the transmission of water vapors and is equal to one grain of water vapor transmitted per ft^2 per hour per inch of mercury pressure difference. The Energy Commission has determined that interior painted surfaces may qualify for meeting the vapor barrier requirement if the paint product is tested to have a rating of one perm or less. For all types of vapor barriers, care should be taken to seal penetrations such as electric outlets on exterior walls.

Products such as a continuous polyethylene sheet or wall board with foil backing qualify as vapor barriers, if according to the appropriate testing procedure, they meet the vapor barrier permeance rating of one perm or less. Kraft paper backing on batt insulation, under certain circumstances, may be used to meet the continuous vapor barrier requirement. Specifically, the paper backing must meet the vapor barrier permeance rating, and the product must be installed properly.

For proper installation of batt insulation with Kraft paper backing (see Figure 3-28):

1. The Kraft paper should *not* be stapled to the sides of framing members; instead, the Kraft paper tabs on each side of the insulation batt must be fastened to the face of the conditioned side of the framing member, and
2. At the ends of the insulated cavity, the Kraft paper must overlap the framing members to create a continuous barrier at the wall cavity. Also see Wall Insulation in Reference Residential Appendix RA3.5 and RA3.5.4 for further insulation procedures.

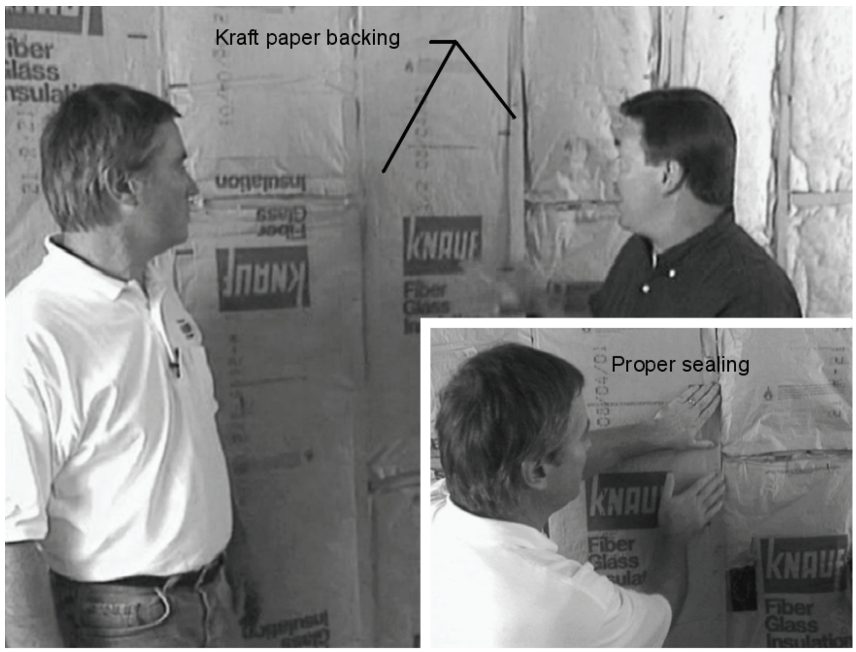

Figure 3-28 – Vapor Barriers with Kraft Paper

3.7 Roofing Products (Cool Roof)

Roofing products with high solar reflectance and thermal emittance are referred to as “cool roof”, which is the outer layer or exterior surface of a roof. As the term implies, the temperature of a cool roof is lower on hot sunny days than for a conventional roof, reducing cooling loads and the energy required to provide air conditioning. Compliance credit may be taken when a cool roof is installed when using the performance approach. The credit is available only if there is no radiant barrier installed. In the performance method calculations, the cooling benefit of a cool roof is assumed to be equal to that of a radiant barrier. There is no heating impact calculated for a cool roof (while there is some heating benefit assumed for a radiant barrier).

The benefit of a high reflectance surface is obvious: while dark surfaces absorb the sun’s energy (visible light, invisible infrared. and ultraviolet radiation) and become hot, light-colored surfaces reflect solar energy and stay cooler. However, high emittance is also important. Emittance refers to the ability of heat to escape from a surface once it is absorbed. Surfaces with low emittance (usually shiny metallic surfaces) contribute to the transmission of heat into the roof components under the roof surface. However, due to increase of heat, the building's air conditioning load will result in an increased of the air conditioning load and less comfort for the occupants. High-emitting roof surfaces give off absorbed heat relatively quickly through the path of least resistance—upward and out of the building.

3.7.1 Mandatory Measures

§118(i)

Roofing Products Solar Reflectance and Thermal Emittance

All roofing products must meet the mandatory requirements of §10-113 and §118(i), Rating and Labeling

Roofing products that are used for compliance with the standards (prescriptive and performance approaches) are required to be tested and labeled by the Cool Roof Rating Council (CRRC) per §10-113 and that liquid applied products meet minimum standards for performance and durability per §118(i)4. The CRRC is the supervisory entity responsible for certifying cool roof products. The CRRC test procedure is documented in CRRC-1, the CRRC Product Rating Program Manual. This test procedure includes tests for both solar reflectance and thermal emittance.

The roofing products manufacturer must have its roofing product tested for solar reflectance and thermal emittance, and be listed in the CRRC's Rated Product Directory (see http://www.coolroofs.org) and be labeled according to CRRC procedures. Figure 3-29 provides an example of an approved CRRC product label.

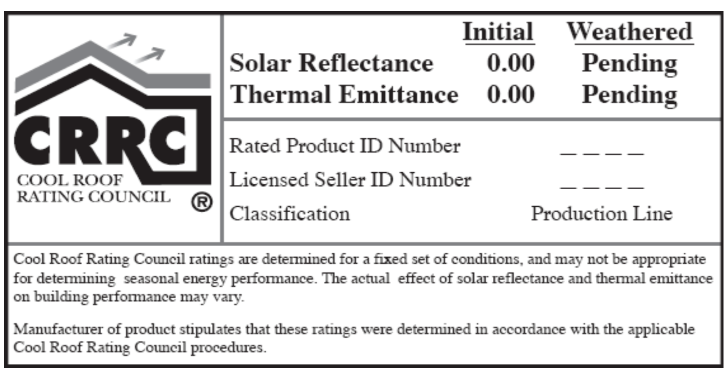

Figure 3-29- CRRC Product label and information

If the aged value for the reflectance is not available in the CRRC's Rated Product Directory then the equation below can be used until the aged rated value for the reflectance is posted in the directory.

Aged $\text{Reflectance}_{\text{calculated}}=(0.2+0.7[\rho_{\text{initial}} - 0.2])$

Where ρ_{initial} = Initial Reflectance listed in the CRRC Rated Product Directory.

3.7.2 Prescriptive Requirements

§151 (f)12
Prescriptive Standards Roofing Product

The prescriptive requirements call for a cool roof in both low-slope and steep-slope applications for residential buildings. A low-slope roof is defined as a surface with a pitch less than or equal to 2:12 (9.5 degrees from the horizontal or less) while a steep-slope roof is a surface with a pitch greater than 2:12 (more than 9.5 degrees from the horizontal). The prescriptive requirements for cool roofs under the new 2008 Standards are now climate zone dependent and the aged reflectance and emittance criteria depend on the type of roofing material being used.

The residential roofing product requirement in the prescriptive package is as follows. For steep-sloped applications in climate zones 10-15, for roofing products that have a density of less than 5 lb/ft^2 (generally, asphalt shingle and metal products) there is a three year aged solar reflectance requirement of 0.20 and a (three year aged or initial) thermal emittance requirement of 0.75, or a minimum solar reflectance index (SRI) of 16. For roofing products with a density of 5 lb/ft^2 or more (generally include concrete, clay tiles, slate and possibly some synthetic roof coverings), in climate zones 1-16, there is a minimum aged solar reflectance of 0.15 and thermal emittance of 0.75, or a minimum SRI of 10.

For low-sloped roofing applications, in climate zones 13 and 15, there is a minimum aged solar reflectance of 0.55 and thermal emittance of 0.75, or a minimum SRI of 64.

There are two exceptions to meeting the roofing products requirements in the prescriptive package:

1. The roof area with building integrated photovoltaic panels and building integrated solar thermal panels are exempt from the minimum requirements for aged solar reflectance and thermal emittance or SRI Exception 1 to §151(f)12.
2. If roof constructions that have thermal mass over the roof membrane with a weight of at least 25 lb/ft^2 are exempt from the minimum requirements for aged solar reflectance and thermal emittance or SRI under Exception 2 to §151(f)12.

Solar Reflectance Index (SRI)

Solar Reflectance Index (SRI) is a new concept in the 2008 Standards; in lieu of meeting a thermal resistance and solar reflectance requirement, compliance can be shown by meeting a minimum SRI. The temperature of a surface depends on the surface's reflectance and emittance, as well as solar radiation. The SRI measures the relative steady-state surface temperature of a surface with respect to the standard white (SRI=100) and standard black (SRI=0) under the standard solar and ambient condition. A calculator was produced by the staff at Lawrence Berkeley National Laboratory which calculates the SRI by designating the solar reflectance and thermal emittance of the desired roofing material. The calculator can be found at http://www.energy.ca.gov/title24/2008standards. SRI calculations shall be based on moderate wind velocity of 2-6 meters per second to calculate the SRI the 3-year aged value of the roofing product must be used. By using the SRI calculator a cool roof may comply with an emittance lower than 0.85 as long as the aged reflectance is higher. Also, SRI can be obtained by trading off a lower aged solar reflectance with a higher thermal emittance.

In addition to the questions and answers below about cool roofs, the 2008 Nonresidential Manual contains more cool roof information (including different questions and answers) in Section 3.4.

Example 3-23

Question

Is a cool roof required in new residential construction or in residential alterations or additions?

Answer

Yes, for the 2008 Standards cool roof is required when using the prescriptive package in new residential construction, additions or alterations. Cool roof now applies to both low-slope and steep-slope residential roofs. Also, the cool roof requirement is different per climate zone and per the type of product being used (product weighing less than 5 lbs/ft² or 5 lbs/ft² or more). If one wishes not to install a cool roof then they must meet the Standards using the performance method where tradeoffs can be done.

Example 3-24

Question

I am a salesperson and represent some roofing products, and many of them are on the EPA's Energy Star list for cool roofing materials. Is this sufficient to meet Standards?

Answer

No. Energy Star has different requirements for reflectance and NO requirements for emittance. The Cool Roof Rating Council (http://www.coolroofs.org) is the only entity currently recognized by the Energy Commission to determine what qualifies as a cool roof under.

Example 3-25

Question

How does a product get CRRC cool roof certification?

Answer

Any party wishing to have a product or products certified by CRRC should contact CRRC to get started call toll-free (866) 465-2523 from inside the US or (510) 485-7176, or email info@coolroofs.org. CRRC staff will walk interested parties through the procedures. In addition, CRRC publishes the procedures in "CRRC-1 Program Manual," available for free on http://www.coolroofs.org or by calling CRRC. However, working with CRRC staff is strongly recommended.

Example 3-26

Question

I've heard the words reflectivity, reflectance, emissivity, and emittance? Can you explain?

Answer

"Reflectivity" and "reflectance" denote the same thing, but the Standards use only "reflectance" to avoid confusion. "Emissivity" and "emittance" denote the same thing, and again the Standards use only "emittance."

Example 3-27

Question

I understand reflectance, but what is emittance?

Answer

Even a material that reflects the sun's energy will still absorb some of that energy as heat; there are no perfectly reflecting materials being used for roofing. That absorbed heat undergoes a physical change (an increase in wavelength, for readers who remember physics) and is given off – emitted – to the environment in varying amounts by various materials and surface types. This emittance is given a unitless value between 0 and 1, and this value represents a comparison (ratio) between what a given material or surface emits and what a perfect blackbody emitter (again, recall physics) would emit at the same temperature.

A higher emittance value means more energy is released from the material or surface; scientists refer to this emitted energy as thermal radiation (as compared to the energy from the sun, solar radiation, with shorter wavelength). Emittance is a measure of the relative efficiency with which a material, surface, or body can cool itself by radiation. Lower-emitting materials become relatively hotter for not being able to get rid of the energy, which is heat. Roof materials with low emittance therefore hold onto more solar energy as heat, get hotter than high-emittance roofs, and with help from the laws of physics, offer greater opportunity for that held heat to be given off downward into the building through conduction. More heat in the building increases the need for air conditioning for comfort. A cool roof system that reflects solar radiation (has high reflectance) and emits thermal radiation well (has high emittance) will result in a cooler roof and a cooler building with lower air-conditioning costs.

3.8 Compliance and Enforcement

Chapter 2 addresses general compliance and enforcement issues, the roles and responsibilities of each of the major parties, the compliance forms, and the process for field verification and/or diagnostic testing. This section highlights some of the compliance and enforcement issues specifically for the building envelope.

3.8.1 Design

The initial compliance documentation consists of the Certificate of Compliance (CF-1R). With the 2008 update, MF-1R is no longer a checklist, but a statement of the mandatory features to be included with the CF-1R forms. The mandatory features are also included in the CF-6R forms. The CF-1R must be filed on the plans and specifications. Included on the CF-1R is a section where special envelope features are listed. The following are envelope features that should be listed in this section if they exist in the proposed design:

1. Inter-zone ventilation
2. Radiant barriers
3. Multiple Orientation
4. Controlled ventilation crawlspace
5. Non-standard ventilation height differences
6. Standard free ventilation area greater than 10 percent of the window area

7. High thermal mass features
8. Metal-framed walls
9. Sunspace with interzone surfaces
10. Roofing products (Cool roof)
11. Air retarding wrap

Plan checkers should verify that insulation levels, fenestration U-factors, and SHGCs listed on the CF-1R are consistent with the plans and specifications.

If registration of the CF-1R is required (see Chapter 2 for requirements), the building owner, or the person responsible for the design must submit the CF-1R to the HERS provider data registry for retention following the procedures described in Chapter 2 and in Reference Residential Appendix RA2.

3.8.2 Construction

During the construction process, the contractor and/or the sub-contractors complete the necessary sections of the Installation Certificate (CF-6R):

1. Fenestration/Glazing. The glazing contractor lists all the fenestration products that are installed in the building along with the model number, the manufacturer number, the U-factor and the SHGC.
2. Building Envelope Leakage Diagnostics. This is applicable only if the builder/contractor does blower door testing to reduce building envelope leakage.
3. Insulation Installation Quality Certificate. The insulation contractor documents the insulation installation quality features that have been followed as shown on the CF-6R checklist.
4. Description of Insulation. The insulation contractor documents the insulation materials installed in the walls, roofs, and floors along with the brand name of the materials and the thermal resistance.

The building official (field inspector) will visit the site multiple times during the construction process. The purpose of these visits is to verify that the equipment and materials installed are consistent with the plans and specifications.

If registration of the CF-6R is required, the licensed person responsible for the installation must submit the portion of the CF-6R information that applies to the installation to a HERS provider data registry using procedures described in Chapter 2 and in Reference Residential Appendix RA2.

3.8.3 Field Verification and/or Diagnostic Testing

For buildings for which the Certificate of Compliance (CF-1R) requires HERS field verification for compliance with the standards, a HERS rater must visit the site to perform field verification and diagnostic testing, to complete the applicable Envelope portions of a Certificate of Field Verification and Diagnostic Testing (CF-4R).

The following measures require field verification and diagnostic testing if they are used in the proposed design for compliance, and are listed on the CF-1R as special features requiring HERS rater verification:

1. Building Envelope Sealing
2. Quality Insulation Installation (QII)
3. Quality Insulation Installation (QII) for Spray Polyurethane Foam

Field verification is necessary only when credit is taken for the measure. For example, Building Envelope Sealing need only be HERS verified if Building Envelope Sealing was used to achieve credit in the proposed design.

Registration of the CF-4R is required. The HERS rater must submit the CF-4R information to the HERS provider data registry as described in Chapter 2. For additional detail describing HERS verification and the registration procedure, refer to Reference Residential Appendix RA2.

3.9 Glossary/Reference

The Reference Joint Appendices JA1 contains a glossary of terms. For definitions of terms used in this manual refer to that section of the Reference Joint Appendices. The following terms either expand on those definitions or are not listed there.

Fenestration Terminology

The following terms are used in describing fenestration products.

- **Center of Glass U-factor or Solar Heat Gain Coefficient (SHGC).** The U-factor or SHGC are measured only through glass at least 2.5 inches from the edge of the glass or dividers.
- **Clear.** Little if any observable tint. An IG unit with an SHGC of 0.5 or greater.
- **Divider (Muntin).** An element that actually or visually divides different lites of glass. It may be a true divided lite, between the panes, and/or applied to the exterior or interior of the glazing.
- **Fixed.** The fenestration product cannot be opened.
- **Gap Width.** The distance between glazings in multi-glazed systems (e.g., double-or triple-glazing). This dimension is measured from inside surface to inside surface. Some manufacturers may report "overall" IG unit thickness which is measured from outside surface to outside surface.
- **Grille.** See Divider.
- **IG Unit**. Insulating glass unit. An IG unit includes the glazings, spacer(s), films (if any), gas infills, and edge caulking.
- **Hard Coat.** A pyrolytic low-e coating that is generally more durable but less effective than a soft coat. See separate glossary term for low-e coating.

- **Light or Lite.** A layer of glazing material, especially in a multi-layered IG unit. Referred to as panes in §116 when the lites are separated by a spacer from inside to outside of the fenestration.
- **Low-e Coating.** A transparent or semitransparent metallic coating applied to glazing that reduces the emittance of the surface and that usually affects the solar heat gain of the glass. Low-e stands for low-emissivity. The coating (or film) is generally between glazings in double-pane or triple-pane fenestration products.
- **Mullion.** A frame member that is used to join two individual windows into one fenestration unit.
- **Muntin.** See Dividers.
- **Nonmetal Frame.** Includes vinyl, wood, or fiberglass. Vinyl is a polyvinyl chloride (PVC) compound used for frame and divider elements with a significantly lower conductivity than metal and a similar conductivity to wood. Fiberglass has similar thermal characteristics. Non-metal frames may have metal strengthening bars entirely inside the frame extrusions or metal-cladding only on the surface.
- **Operable.** The fenestration product can be opened for ventilation.
- **Soft Coat.** A low-e coating applied through a sputter process. See separate glossary term for low-e coating.
- **Spacer.** A material that separates multiple panes of glass in an insulating glass unit.
- **Thermal Break Frame.** Includes metal frames that are not solid metal from the inside to the outside, but are separated in the middle by a material, usually vinyl or urethane, with a significantly lower conductivity.
- **Tinted.** Darker gray, brown or green visible tint. Also, low-e or IG unit with an SHGC less than 0.5.

Low-e Coatings

Low-emissivity coatings are special coatings applied to the second or third surfaces in double-glazed windows or skylights. As the name implies the surface has a low emittance. This means that radiation from that surface to the surface it “looks at” is reduced. Since radiation transfer from the hot side of the window to the cool side of the window is a major component of heat transfer in glazing, low-e coatings are very effective in reducing the U-factor. They do nothing, however, to reduce losses through the frame.

In the residential market, there are two kinds of low-e coatings: low solar gain and high solar gain. Low-solar gain low-e coatings are formulated to reduce air conditioning loads. Fenestration products with low solar gain low-e coatings typically have an SHGC of 0.40 or less, and meet the SHGC prescriptive requirements for California’s cooling climates. Low-solar gain low-e coatings are sometimes called spectrally selective coatings because they filter much of the infrared and ultra-violet portions of the sun’s radiation while allowing visible light to pass through. High solar gain low-e coatings, by contrast, are formulated to maximize solar gains. Such coatings would be preferable in passive solar applications or perhaps in mountainous climates where heating loads are significant and there is little air conditioning.

Low-e coatings are applied in one of two ways. Pyrolytic low-e coatings are applied while the glass is being manufactured and while it is still very hot. Pyrolytic hard coat low-e coatings are sometimes called “hard” low-e coatings because they are more durable and resistant to scratching. Sputtered low-e coatings are applied after the glass leaves the float line and has been cut to size. The cut glass passes through a series of vacuum chambers where layers of metal are deposited on the surface of the glass to create precise solar optical properties. Sputter coatings are sometimes called “soft” coatings because they are less durable. Both soft and hard low-e coatings are typically positioned on the second or third surface so that they are protected from abrasion.

Another advantage of low-e coatings, especially low solar gain low-e coatings, is that when they filter the sun’s energy, they generally remove between 80 percent and 85 percent of the ultraviolet light that would otherwise pass through the window and damage fabrics and other interior furnishings. This is a major advantage for homeowners and can be a selling point for builders.

National Fenestration Rating Council

The National Fenestration Rating Council (NFRC) is the entity recognized by the Energy Commission to supervise the rating and labeling of fenestration products. NFRC list the Certified Product Directory, containing NFRC certified U-factors and SHGC values for thousands of products (see http://www.nfrc.org or call 301-589-1776.)

Fenestration product performance data used in compliance calculations must be provided through the NFRC rating program and must be labeled by the manufacturer with the rated U-factor and SHGC in accordance with §10-111 procedures.

R-value

R-value is a measure of a material’s thermal resistance, expressed in $ft^2(hr)°F/Btu$. R-value is the inverse of U-factor. A higher R-value and lower U-factor indicate higher energy efficiency.

The rated R-value of fiberglass (batt) insulation is based upon its fully expanded thickness and may be obtained from the Reference Joint Appendices JA4, Table 4.6.2 or from the manufacturer’s literature. When the insulation is compressed, the R-value is reduced. The most common insulation compression occurs with R-19 and R-22 insulation batts installed in locations with a nominal 6-inch framing that is actually only 5.5 in. thick. To achieve its rated insulation value, an R-19 batt of insulation expands to a thickness of six and one quarter inches. If it is compressed into 2x6 framing with an actual depth of 5.5 inches, the insulation R-Value is lowered to 17.8.

Solar Heat Gain Coefficient

Solar heat gain coefficient (SHGC) is a measure of the relative amount of heat gain from sunlight that passes through a fenestration product. SHGC is a number between zero and one that represents the ratio of solar heat that passes through the fenestration product to the total solar heat that is incident on the outside of the window. A low SHGC number (closer to 0) means that the fenestration product keeps out most solar heat. A higher SHGC number (closer to 1) means that the fenestration product lets in most of the solar heat.

$SHGC_c$ is the SHGC for the center of glazing area; SHGC or $SHGC_t$ is the SHGC for the total fenestration product and is the value used for compliance with the Standards.

U-factor of Fenestration Products

U-factor is a measure of how much heat passes through a construction assembly or, for this chapter of the manual, a fenestration product. The lower the U-factor, the more energy efficient the product is. The units for U-factor are Btu of heat loss each hour per ft^2 of window area per degree °F of temperature difference (Btu/hr-ft^2-°F). U-factor is the inverse of R-value.

The U-factor considers not just the losses through the center of the glass, but also losses at the edge of the glass where a metal spacer is typically used to separate the double-glazing panes, losses through the frame, and losses through the mullions. For metal-framed windows, the frame losses can be quite significant, even larger in some cases than heat losses through the glass.

U-factor_c is the U-factor for the center of glazing area; U-factor_t is the U-factor for the total fenestration product and is the value used for compliance with the Building Energy Efficiency Standards.

Estimating the rate of heat transfer through a fenestration product is complicated by the variety of frame configurations for operable windows, the different combinations of materials used for sashes and frames, and the difference in sizes available in various applications. The NFRC rating system makes the differences uniform, so that an entire fenestration product line is assumed to have only one typical size. The NFRC rated U-factor may be obtained from a directory of certified fenestration products, directly from a manufacturer's listing in product literature, or from the product label.